



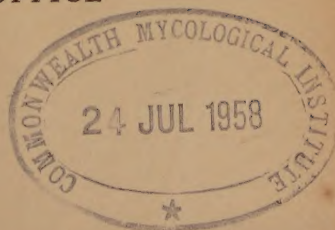
COMMITTEE OF THE PRIVY COUNCIL FOR
AGRICULTURAL RESEARCH

REPORT OF THE
AGRICULTURAL RESEARCH COUNCIL
FOR THE YEAR 1956-57

*Presented to Parliament by the Lord President of the Council
by Command of Her Majesty
May 1958*

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REPORT OF THE COMMITTEE OF PRIVY COUNCIL FOR AGRICULTURAL RESEARCH FOR THE YEAR 1956-57

TO THE QUEEN'S MOST EXCELLENT MAJESTY,
MAY IT PLEASE YOUR MAJESTY,

We, the Lords of the Committee for Agricultural Research of Your Majesty's Privy Council, humbly submit to Your Majesty a Report of our proceedings during the year from 1st April, 1956 to 31st March, 1957.

On the 1st April, 1956, there came into force the Agricultural Research Act, 1956, which established an Agricultural Research Fund into which are to be paid such sums as may from time to time be provided by Parliament for agricultural research and from which are paid all expenses incurred by the Agricultural Research Council under the Act or in accordance with its Charter. By the passage of this Act the Council was made directly responsible to Parliament for its expenditure instead of, as previously, having this borne on the Treasury Vote. The occasion for this change arose from the decision of Government, following a recommendation of the Select Committee on Estimates of the House of Commons, to transfer to the Council from the 1st April, 1956 the responsibility hitherto exercised by the Ministry of Agriculture, Fisheries and Food for financing the State-aided agricultural research institutes in England and Wales. The year under report is therefore the first during which this important change in the administration of agricultural research has been in operation. We are satisfied that the new arrangements are working well and are contributing to greater efficiency.

During the financial year 1956-57, Parliament provided a total of £3,626,000 as a grant in aid of the Agricultural Research Fund, of which £3,560,000 was by the Original Estimate and £66,000 by Supplementary Estimate. This total was based on estimated current expenditure of £3,339,500 gross, receipts of £272,000 and capital expenditure of £558,500 on buildings and special apparatus.

The estimates of the Agricultural Research Council for that financial year were met by our provisional allocation of funds under the following heads:

For administration, including the expenses of the Council and of the administrative offices and staff;

For the current expenditure, including salaries and wages of the staffs, of the Council's Institutes and Units;

For grants for current expenditure, including salaries and wages, to State-aided research institutes in England and Wales;

For grants for special research schemes;

For Training Awards, Fellowships and visits abroad;

For capital expenditure, mainly on new buildings, for the Council's research institutes and units and for the State-aided research institutes.

Prior to the year under report the Council was responsible to a Committee of Privy Council for Agricultural Research and Nature Conservation, consisting of the Lord President as Chairman and six other Ministers. By an Order in Council dated 1st April, 1956, this Committee was replaced by a Committee of

Privy Council for Agricultural Research consisting of the Lord President (Chairman), the Minister of Agriculture, Fisheries and Food (Vice-Chairman) and the Secretary of State for Scotland.

With the expansion of the Council's responsibilities, it was decided to enlarge the membership of the Council to provide for representation of the two Agricultural Departments and for the appointment to it, as *ex officio* members, of the Chief Veterinary Officer and the Chief Scientific Adviser (Agriculture) of the Ministry of Agriculture, Fisheries and Food. By another Order in Council a Supplemental Charter giving effect to these changes in membership of the Council was granted on the 28th May, 1956. From that date the membership of the Council was as follows:—

The Lord Rothschild, G.M., M.A., Sc.D., Ph.D., F.L.S., F.R.S. (Chairman)	} Appointed by the Committee of Privy Council for the Organisation and Develop- ment of Agricultural Research
Professor Sir Hans Krebs, M.A., M.D., F.R.S.	
David Lowe, C.B.E.	
Professor E. J. Maskell, M.A., Ph.D., F.R.S.	
Professor K. Mather, C.B.E., D.Sc., Ph.D., F.R.S.	
Professor P. B. Medawar, C.B.E., D.Sc., Ph.D., F.L.S., F.R.S.	
Professor L. P. Pugh, M.A., B.Sc., F.R.C.V.S.	
Frank Rayns, C.B.E., M.A.	
Sir James Turner, B.Sc., LL.D.	
Professor S. J. Watson, D.Sc., F.R.I.C., F.R.S.E. (Deputy Chairman)	
Professor J. S. Young, M.C., M.A., B.Sc., M.D.	
Professor Sir Solly Zuckerman, C.B., M.A., M.D., D.Sc., F.R.S.	
Professor H. G. Sanders, M.A., Ph.D.	} Chief Scientific Adviser (Agriculture) Ministry of Agriculture, Fisheries and Food
J. N. Ritchie, C.B., B.Sc., F.R.C.V.S., D.V.S.M., F.R.S.E.	
W. C. Tame	} Appointed by the Minister of Agriculture, Fisheries and Food
L. G. Davidson, C.B.	
	} Appointed by the Secretary of State for Scotland

On the 1st October, 1956, we appointed (after the required consultation with the Agricultural Research Council and with the President of the Royal Society) Ronald Everett Glover, M.A., B.Sc., F.R.C.V.S. (Principal of the Royal Veterinary College) to be a member of the Council in the vacancy caused by the retirement, on the 18th May, 1956 after nine years service as a member, of Sir Roy Cameron, M.B., B.S., D.Sc., F.R.C.P., F.R.S. (Professor of Morbid Anatomy, University College Hospital Medical School). We also re-appointed from the 3rd October, 1956 for a second term of five years Stephen John Watson, D.Sc., F.R.I.C., F.R.S.E. (Professor of Agriculture and Rural Economy, University of Edinburgh).

The Agricultural Research Act, 1956 provides that the Agricultural Research Council shall in respect of each year prepare and submit to the Committee of Privy Council for Agricultural Research a report of the proceedings of the Council during that year for presentation to Parliament. We have received from the Agricultural Research Council a Report, which is submitted herewith, upon the progress of their work during the year which ended on the 31st March, 1957. This Report is the first to be rendered in accordance with the requirements of that Act.

Scientific liaison with other parts of the Commonwealth and with the United States of America and other countries has been actively continued.

Close touch has been maintained with the Ministry of Agriculture, Fisheries and Food and with the Department of Agriculture for Scotland. There has also been co-operation with the Colonial Office, and, on research questions of common interest, the normal consultations with the Medical Research Council and the Department of Scientific and Industrial Research.

On behalf of the Lords of the Committee for Agricultural Research of Your Majesty's Privy Council.

HAILSHAM,

Lord President of the Council.

W. K. SLATER,

*Secretary to the Committee of Privy Council
for Agricultural Research.*

14th April, 1958.

REPORT OF THE AGRICULTURAL RESEARCH COUNCIL FOR THE YEAR 1956-57

To the Lords of the Committee of Privy Council for Agricultural Research.

May it please your Lordships,

The Agricultural Research Council beg leave to submit the following Report upon their proceedings during the period from 1st April, 1956 to 31st March, 1957.

INTRODUCTION

EARLY DEVELOPMENT OF AGRICULTURAL RESEARCH

As this is the first Annual Report to Parliament of the Agricultural Research Council, it seems fitting to begin with a brief description of the origins of the Council and of the way the Council works.

In its early days, agricultural research was not centrally organised at all. It began by the action of individuals who, either alone or in associations, founded and were the first to maintain the older research institutes. The history of Rothamsted—the oldest agricultural research institute—is in several respects typical. Sir John Lawes founded the institute in 1843 and for many years personally financed its work, until, in 1889, he endowed the institute and set up the Lawes Agricultural Trust to administer the income from the endowment. When its success became apparent, other individuals and public bodies contributed money to promote further research. After some years, public subscription became inadequate to meet the enlarged scale of research and Government funds were sought and obtained. As research became more costly, the proportion of the expenses met by Government sources rose to the present figure of 90 per cent. Rothamsted nevertheless remains an independent institution administered by the Lawes Agricultural Trust, subject to the conditions under which the Grant-in-Aid is made. The same general pattern has been followed in other institutes receiving their income from Government sources as Grant-in-Aid.

Other more recently founded research institutes were begun wholly or largely by personal benefactions. Some were formed by associations of farmers or horticultural growers to deal with the special problems of their own branches of the industry. Others were officially sponsored to fill gaps in the service and were organised on the same pattern as the older institutes, with independent Governing Bodies who serve unpaid and administer them. There are 22 agricultural research institutes with this type of constitution, generally referred to as the State-aided Institutes to distinguish them from those under direct Government control. They draw the greater part of their funds from the State; those in Scotland do so from the Department of Agriculture for Scotland on the advice of the Agricultural Research Council and those in England and Wales direct from the Council. A list of these State-aided Institutes is given on page 142.

The Development and Road Improvement Act of 1909, which first made Government money available for agricultural research, also founded the organisation to co-ordinate it, the Development Commission, which was made responsible for the allocation of funds. After a temporary check caused by the First

World War, agricultural research rapidly expanded and grew more complex and new problems of co-ordination arose. In 1931 the Agricultural Research Council was established by Royal Charter to be responsible for the general organisation and development of agricultural research in Great Britain. Apart from advising the Agricultural Departments on the programmes of the institutes and, in the early stages, acting as scientific advisers to the Development Commission, the Council was given funds to spend at its own discretion. When fully established, the Council gradually took over the responsibilities for agricultural research formerly discharged by the Development Commission, and on the 1st April, 1956, became responsible for providing the Government grants for the State-aided Institutes in England and Wales. This function had previously been fulfilled by the Ministry of Agriculture, Fisheries and Food, acting on the Council's advice. A similar policy, of establishing a single source of control, was not followed in Scotland because Government, accepting the recommendations of the Royal Commission on Scottish Affairs, decided that it was more advantageous to preserve the existing arrangement: by this, the State-aided Institutes in Scotland are provided with grants from the Vote of the Department of Agriculture for Scotland and the Council's role is limited to advising the Department on the research programmes of these institutes and on the necessary scientific staff and facilities.

DEVELOPMENT OF RESEARCH UNDER THE COUNCIL

One of the first acts of the Agricultural Research Council when it came into being was to survey the field already covered by the existing agricultural research institutes. Work on many subjects was shown to be required, but of these, research on the diseases of farm animals was the most urgent. Research on large farm animals is expensive, requiring land, equipment and organisation on a large scale; it was therefore decided to set up new stations to be financed and administered directly by the Council. The Field Station at Compton was the first institute of this kind, and it was followed by three more institutes for research on animals and by a number of smaller research units to deal with special aspects of this subject. A list of the Council's institutes and units is given on page 143.

The units which the Council has set up are, for the most part, closely associated with Universities and the Director (or honorary Director) of a unit usually holds a substantive post of Professor or Reader in the University. The graduate staff of the unit are, however, employed by the Council, which also meets the running costs of the unit. These units enable the Council to assist the development of a field of research in a University under a recognised leader, to an extent that would not normally be possible within the confines of a University Department. A unit is usually disbanded when the leader around whom it was built retires or leaves.

Apart from setting up research units, the Council also finances research in Universities through special research grants. These grants are normally made to assist projects of short duration. A fuller account of them and a description of the current grants will be found later in this Report.

The Council's main functions are to review, co-ordinate and facilitate research in progress, promote new research where necessary, and ensure that manpower and resources are used to the best advantage. To do this, the Council's immediate responsibility is to see that the many able scientists engaged in agricultural research are given the best possible conditions for their work and guidance where necessary. The Council must work through these men and women in planning and executing its research programme.

While the Council itself must consider all broad questions of policy and, particularly, those financial matters requiring its sanction, the diversity of its interests demands that some of its work should be delegated. It has, therefore, set up two Standing Committees. One deals with research concerning animals and the other with research concerning plants and soils. These give detailed and specialised consideration to problems in their separate fields and advise the Council on any action which may be needed. To these Standing Committees are appointed those members of Council whose main interests lie in the appropriate field, together with other scientists of repute, whose specialised knowledge on the many different scientific interests involved is necessary.

The work is further broken down, as is described later, into a number of committees, conferences and *ad hoc* groups, which report to the Council through one or other of the Standing Committees. A list of these committees and conferences as at present constituted will be found on pages 145-152.

SELECTION OF PROBLEMS FOR INVESTIGATION

The problems of the agricultural industry which require research are formulated, and their relative importance assessed, by the Ministry of Agriculture, Fisheries and Food and the Department of Agriculture for Scotland, as these are concerned with agricultural policy and development. Policy often influences the practice of research in that it determines the priority of problems needing scientific investigation; conversely, new materials and methods produced by the research service influence development. The existence of two Agricultural Improvement Councils—one for England and Wales and one for Scotland—therefore allows constant exchange of ideas between the Agricultural Research Council and the Departments. The Improvement Councils advise the Departments how best the results of research may be put into farming practice as quickly as possible; they also advise the Agricultural Research Council about problems which they consider require investigation. A Joint Committee of the Agricultural Research Council and the two Agricultural Improvement Councils facilitates consultation and action on matters of common interest to all three bodies. The chief function of the Joint Committee is to co-ordinate research with the needs of the industry and so lead to improved efficiency. With this objective, at the suggestion of the Agricultural Research Council, the Joint Committee began, in 1954, to review the whole field systematically, commodity by commodity, using as a basis memoranda prepared by experts after consultation with members of the industry and with research and advisory workers. The Joint Committee's examination of these memoranda falls into two parts. The first is to determine the most important problems that concern each major commodity, to classify these problems under subject headings, and to arrange them in order of priority. The second stage is to review the research in progress in the light of the priorities allocated and other relevant factors, and to make the appropriate recommendations.

It would be impossible for everything to pass through the formal machinery designed to keep Council informed of the problems of the industry. In practice, the research workers hear of the farmers' problems from the advisory officers of the National Agricultural Advisory Service in England and Wales and of the Agricultural Colleges in Scotland, and from the farmers themselves. The advisory officers are in close touch with the research workers in the institutes and this liaison takes place in a number of informal ways. Research workers regularly attend technical discussions held by advisory officers and there is a frequent exchange of visits; the research workers go into the field to lecture, demonstrate and assist with experiments on commercial farms or on the Experimental

Husbandry Farms and Horticultural Stations of the Advisory Service. For their part, the advisory officers visit the research institutes as often as they can.

Each year thousands of farmers go to the research institutes, either singly or in organised parties, meeting the staff and seeing the work in progress. Many of the institutes have membership schemes: on the payment of a small subscription, farmers, through their elected representatives on the Governing Body, are able to take a part in the running of the institute, and they receive annual reports of the work in progress. Other institutes without membership schemes have on their Governing Bodies farmers nominated for their outstanding knowledge and ability. It is rare, therefore, for any formal representation to bring to light a problem of which the research workers are not already aware.

The individual farmer and the advisory officer are, however, too closely associated with one particular branch of farming or with farming in one limited area to be able to assess the importance of their own problems compared with those which they do not meet. The scientist, from the very nature of his work, is a specialist who tends to see a single aspect of agriculture and to meet only the farmers and advisory officers with the same interest as himself. A disproportionate effort may be applied to one problem, due to local or sectional pressures, or because the staff and equipment are immediately available for the work; on the other hand, another problem may be relatively neglected on account of its more general character or because the men and facilities are not so readily available.

It is highly desirable that the impetus and drive for research should, so far as possible, come from the research workers themselves, who are in touch with the farmers and the advisory services. On the other hand, such an arrangement would, in the absence of other guidance, tend to result in an unbalanced distribution of effort. It is the Agricultural Research Council's task to try to adjust this balance without destroying the enthusiasm of the scientist and the interest and support of the farmers.

In this task, the Council relies on the Improvement Councils and the Joint Committee which keep continuous watch on the needs of the industry and so are able to assign priorities to the different problems. As the commodity surveys carried out by the Joint Committee become available, they will be used by the Council in order to deploy its resources in the best possible way.

THE IMPORTANCE OF FUNDAMENTAL RESEARCH

So far only the selection of the applied problems for investigation has been considered. In order to solve these problems, it is essential to be able to draw on a large store of fundamental scientific knowledge. Without such knowledge, it would be impossible to begin work on most of the applied problems. This store of scientific information comes from research workers all over the world and is contained in a vast literature which is available to all workers. As we must use this knowledge, we clearly have a moral obligation also to contribute to it. While the Council regards this as a sufficient reason in itself for fostering basic research, another and equally important consideration is that research of this type can be directed by the Council so that it supplies scientific knowledge where the need is felt by the applied workers in agricultural research. Thus the Council supports work on the fundamental study of viruses, because many of the most serious diseases of crops and stock are caused by these organisms.

Another reason for encouraging fundamental research in the institutes is the impact which such work has on the applied research going on at the same time. The worker on basic scientific problems who must be equipped with wide reading and originality of thought, stimulates those of his colleagues who are concerned with the immediate practical problems of the industry: the best results may be achieved when the same man can give his attention to both types of research.

Fundamental research is important in yet another way. Farmers and advisory officers cannot recognise those factors which consistently reduce yields and efficiency throughout any crop or type of stock, because they have no comparative information; for example, an endemic disease may be accepted as a normal feature of a crop. The research worker studying the crop intensively may come upon the disease and be able to show how to eliminate it, resulting in an unexpected benefit to agriculture.

THE RANGE OF THE COUNCIL'S WORK

Agriculture is sometimes spoken of as a science; this is an erroneous conception. Agriculture is an industry and, like any other industry, it can only solve its problems by calling on the services of workers in all the pertinent scientific disciplines. It differs, however, from most other industries in the great breadth of its interests. These may be divided into two large groups: the first is concerned with the soil and the crops grown on it; the second with the animals which convert a part of these crops into other human foods. Each of these groups calls on a wide range of scientific disciplines. The first uses the services of the chemist, the physicist and the microbiologist in the study of the soil; and of the biochemist, the plant physiologist, the geneticist, the plant breeder, the plant pathologist and the entomologist in the study of the growing plant or crop. The second calls again on the chemist, the physicist, the biochemist, the microbiologist, the geneticist and the animal breeder; in addition, all the veterinary scientists are needed; they include the physiologist, the pathologist, the bacteriologist, the virologist, the clinician and the parasitologist.

While these two broad divisions must be distinguished, they are interrelated in two respects. A number of major scientific disciplines such as chemistry and physics are common to both. Moreover, since every aspect of agriculture is concerned with living organisms, whatever the science involved, the workers must have a biological outlook. Although the problems on which these workers are engaged may appear to be unrelated, the basic principles and techniques for solving them remain the same, and the scientists studying the problems of one field benefit by their close relationship under the Council with those working in the other. The Council is continually careful not to lose any opportunity of bringing together men working on apparently different problems, who can help each other by exchanging information and expert knowledge.

In another way, the studies of plants and animals are still more closely related: because of the effect of the one on the other, they cannot be studied separately. The grazing animal is the only effective means of measuring the output of a pasture or of judging between two swards. No cutting technique can adequately replace the selective grazing of an animal, either in the estimation of the total quantity of herbage available or of the quality of that which is eaten. At the same time the type of sward is dependent on how it is grazed and, again, no artificial method can replace the effect of the selective grazing, treading and manuring of stock.

The nutrition, growth and many of the diseases of ruminants cannot be studied without a detailed knowledge of the pasture on which they feed. An extreme example of this interrelationship is provided by the condition in cattle known as bloat. This problem falls primarily in the province of the veterinarian, but he can make little progress without the help of pasture experts, with their botanical and chemical knowledge.

Therefore even in this first broad division of the work of the Council into problems affecting crops and those affecting stock, a major degree of co-operation must be ensured between the workers in the two fields. As each group is

subdivided still further into subsidiary groups of related problems, the need for this co-operation grows proportionately. However heterogeneous the problems of agriculture may seem to be, they have an underlying unity, first, because the approach to the problems must be biological in outlook; and, secondly, because of the interdependence of soil, crop and stock. Another of the Council's tasks is, therefore, to knit together the many different strands of research, each of which in its own way is serving the ends of agriculture.

One important section of the Council's work, agricultural engineering, does not fall into the field of either of the two Standing Committees. Farming in Britain is so highly mechanised and so much is spent by the industry on the purchase and maintenance of equipment, that a high priority must be given to research into problems of farm mechanisation. These include such subjects as the mechanical equipment suitable for farms of different types, the design of prototype machines to fill gaps in the farmers' needs, the examination of the efficiency of existing machines and the study of different problems connected with fixed equipment, such as glasshouse heating, grain drying and grain storage. Here again this work, carried out largely by engineers and physicists, has to be absorbed into the general body of agricultural research. Often the results of research in crop production cannot be fully utilised until machines have been adapted to meet new requirements.

Another field of work which is similar in character to agricultural engineering is that concerned with farm buildings; this has been remitted to the Agricultural Research Council since the end of the year under review. Work on it will call for further specialists, who, like those in agricultural engineering, will have to be integrated into the general scheme of agricultural research.

THE CO-ORDINATION OF RESEARCH BY THE COUNCIL

The Council has therefore three major tasks: to co-ordinate the work of the many different types of scientists engaged in agricultural research; to ensure that the effort expended on the diverse applied problems of the industry is correctly distributed; and to balance the claims of fundamental and applied research. To carry out these tasks the Council uses several related methods of approach.

The first obvious step is to find out what research is in progress and to try to assess how effectively each piece of work is being done. To list the various projects is relatively easy; to estimate the quality and extent of the effort put into each is more difficult. To assess the quality of the work involves knowledge of the men engaged on it and of the way they are setting about their task.

Each institute receives, at least once every six years, a Visiting Group, which is appointed by the Council and consists of scientists and agriculturalists distinguished in the fields of work covered by the institute. The members of the Group not only examine the programme of future work with the Director, but they also discuss, as far as possible, with individual workers the investigations on which they are engaged. The Group's report, together with the Director's comments on it, is considered by the Council. The Group's recommendations usually prove acceptable both to the Council and to the Director; if not, such further discussions as are necessary to produce agreement take place. The programme agreed in conjunction with a Visiting Group cannot be expected to remain unaltered for the next five or six years, and directors are therefore asked to submit each year in the period between Visiting Groups a note of any changes they propose to make. These changes are considered by the appropriate Standing Committee. If the changes are major, or if the Standing Committee is uncertain of their desirability, members of the Visiting Group are consulted and,

if necessary, the Group can be re-convened, before the Standing Committee makes its recommendation to the Council.

An up-to-date list of the problems under investigation is provided by the programmes of the work in the institutes, which have been agreed in this way. The comments of the Visiting Group on the individual workers and the projects on which they are engaged form a valuable guide to the Council in gauging how far the effort devoted to a problem is adequate in relation to its importance.

A summary is made of all the investigations in progress, by analysing and cross-indexing the work of all the institutes, units and individual workers supported by the Council or other bodies. This analysis is kept up-to-date at the head office of the Council and is published at intervals of about three years under the title "Index of Agricultural Research".

The Council brings together outside experts and its own research workers through a number of informal committees, conferences and *ad hoc* groups. These may be concerned with a specific crop such as potatoes, or type of stock such as pigs, or with a particular field of investigation such as endocrinology in relation to agriculture, or field water control. The functions and membership of these bodies are reviewed each year.

Members of conferences and *ad hoc* groups are workers in the particular field of work to be discussed; membership is kept as open as possible and new members are added if their personal knowledge may be of value to the deliberations of the conference or group.

Meetings only take place when there is a scientific subject for discussion. The meetings of these conferences and groups have no formal agenda, but it is customary for the members to submit short notes on work in progress. If the group has been selected correctly, workers with related interests from different parts of the Council's research service are brought together. The co-operation which the Council desires to foster begins in these meetings. Workers who have similar interests are encouraged to continue and develop the exchange of ideas started at a meeting by visiting each other at their laboratories, where further discussion can take place at the bench.

Apart from stimulating co-operation, the committees, conferences and groups enable the workers to recognise those fields where more research is necessary. The Director of a research institute can be asked to include in his programme a problem not yet investigated, or to intensify work on one which is being inadequately studied; but a better result may be achieved if the interest of the individual worker is aroused, for he will then try and ensure that the problem is included in the programme of his institute and will attack it with enthusiasm as a self-appointed task. If the policy of allowing research programmes to develop from the interests of the research workers leads to any unequal distribution of effort, this can be corrected and the work of the Council suited to the needs of agriculture.

These meetings also produce suggestions for research which may benefit the farmer either indirectly, by providing the basic information necessary to tackle practical problems, or directly, by solving those problems. Though these problems are important, they may not have been recognised by the farmer. If the claims for a particular piece of work appear to be well founded, the Council can encourage its proposers to test their ideas by further study and experiment.

Meetings of scientists to discuss their common problems also enable them to assess their own work, by its reception when presented to the other members of the group.

Though these committees, conferences and groups greatly help the Council in its task of co-ordinating, guiding and stimulating research, they are not in

themselves sufficient. Members of Council and of its Standing Committees have also an important individual part to play. All those serving the Council are scientists or agriculturalists of distinction and each keeps closely in touch with the work of the Council in his own field by attending the meetings of workers—often in the capacity of chairman—by visiting research institutes as frequently as possible and by discussing problems with the workers themselves at scientific meetings and elsewhere. It rarely happens, therefore, that at a meeting of the Council or of a Standing Committee, a question is raised on which one or more members cannot speak with authority and with an intimate knowledge of the staff engaged on the work and the facilities they enjoy. The Council's Secretariat is also helped and guided in the day-to-day scientific administration of its affairs, since on highly complex and technical matters it is able to refer to the judgment of those distinguished scientists who serve the Council.

The Council believes that work carefully directed to desired ends may, from an administrative point of view, appear to be more tidy than that which springs spontaneously from the interest and enthusiasm of the scientist; but that in the end, the former produce fewer results of importance to agriculture. Moreover, it is unlikely to throw up the outstanding and unexpected returns which result from flashes of inspiration.

DIFFICULTIES IN GUIDING RESEARCH

It is difficult to guide rather than direct work. However carefully the workers are selected, there will inevitably be on the staff of every institute a number of men who have lost inspiration and who, if left alone, will plod along doing repetitive work in a field which has already been exhausted. These men should be directed on to more useful lines. The difficulty is to say when and how. Under the present system, the fact that a man's work is positively directed may imply that he is failing as a scientist. He may, therefore, resist direction, maintaining that what he is actually doing is valuable and important. Direction should begin before the scientist has lost all initiative; if it is started too late, he will make nothing of his new problem. Yet it is difficult to persuade the director of an institute, or his fellow scientists, to say early enough that a man should be directed on to a new problem to suit his more limited ability. There is no easy solution to this difficulty, but it must be overcome if the best use is to be made of the available scientific manpower. The Council is always considering how this end may be achieved with as little disturbance of the scientific staffs as possible: for they greatly value the opportunities for individual development under the present system and are sensitive to any suggestion of direction, in case a general system of directed research should be adopted.

Another difficulty experienced in administering research arises from ever-increasing specialisation, both in knowledge and in techniques. It is often difficult to convince a layman that a biochemist, for example, cannot be transferred easily from one branch of biochemistry to another. The doctrine of complete transferability in the administrative Civil Service is so fully accepted that it is hard to believe that more often than not, a scientist cannot be transferred within the relatively narrow limits of one discipline. Yet the literature on the biochemistry of the proteins, for example, is so large and the techniques so specialised that anyone working in this field can take only a general interest in other branches of biochemistry. If he should be asked to undertake work on the carbohydrates, he would have to spend many months familiarising himself with the literature and, perhaps, work for a period with an expert in the field. Often, therefore, it is difficult to find a useful problem to which a man can be directed in the specialised branch of work with which he is familiar. The older he is and the more entrenched he has become in his subject, the more difficult it is for him to attempt to learn another.

There is a great demand for the type of scientist who is willing to try to solve, or at least examine, a series of different *ad hoc* problems. If, therefore, a man who shows signs of lacking the initiative to plan and carry out a sound programme of work for himself can be persuaded early enough to learn how to deal with a variety of *ad hoc* problems, he may become a valuable member of the research service and find for himself a satisfying career.

The research worker's equipment presents further problems. The scientist is continually experiencing the limitations of the apparatus at his disposal. Used with the maximum precision, his instrument may still not be able to measure precisely enough for his purposes. He can make no more progress without an instrument which is precise to further decimal places and shows the difference he wishes to measure. There is therefore a continuous demand for more expensive apparatus; this, in turn, leads to the concentration of equipment in a limited number of centres, where the specialised workers and their highly skilled technicians are also grouped. This is another factor that prevents the scientist from being mobile in his work. The apparatus available tends to dictate the lines of work which can be undertaken; when a man is moved to a laboratory which does not have the necessary equipment, he must laboriously try to learn new techniques and apply himself to new problems.

Agriculture has special problems of its own. Much of the work must be done in the field. Farms for experimental purposes must be provided and these are often elaborate and costly to maintain. For example, to compare different methods of cultivating fruit trees, orchards must be treated in special ways; this may mean that part of the crop is lost, and at the same time more must be spent on labour than in a normal orchard. Work of this kind can only be undertaken at a limited number of centres and the workers specialising in the study of fruit growing problems must be located there.

Even greater difficulties arise in experimental work with farm animals, particularly in the study of their diseases. The loss of saleable products entails considerable expense, and it is also necessary to farm on a large scale to provide reliable feed for the animals. The Council's Field Station at Compton has 2,000 acres under cultivation, to feed the animals in the experimental compound and the herds of known history from which these animals are drawn. By good husbandry and selling as much as possible, over £100,000 is recovered, which is more than one-third of the running cost of the Station. This is a major farming enterprise which needs skilful management. Facilities similar to those at Compton can only be provided at a very limited number of centres at which the work demanding these conditions must, accordingly, be done. The pattern of agricultural research is largely dictated by the facilities required for field and animal experimentation. Unlike medical research, which apart from its big institute for non-clinical research, has been largely undertaken in units in the teaching hospitals, agricultural research has mostly been carried out in institutes where farmland is available, and only to a lesser degree in the Universities where units are concerned with the more fundamental aspects of agricultural research.

THE APPLICATION OF THE RESULTS OF RESEARCH

Research is of no value to agriculture until it is applied. The Agricultural Improvement Councils provide the formal means for handing on the results of research to the farmer, as they do in the case of communicating the problems of the industry to the Agricultural Research Council. Although the administrative machinery has an important function to perform, it can only carry out a small part of the task.

Long before the results of research are ready to be applied, the course of the work is keenly watched by advisory officers and by many progressive farmers. It is essential that they should do so, as the findings of the research institute are rarely ready to be applied at once; trials in the field under widely differing conditions are nearly always necessary before the results can be recommended to farmers. In practice, the advisory staffs and interested farmers agree with the research workers to test their results as soon as enough information is available to make the risk worth while. Frequently these field trials are in progress while the research worker is still clearing up outstanding points before his research is published. By the time a formal statement can be made to the Improvement Councils, the more progressive farmers are already adopting the results and other farmers are either following their example or being encouraged to do so by the advisory officers.

In another type of investigation, the results cannot be employed without materials or engineering equipment being manufactured. Thus a new herbicide discovered by a research laboratory cannot even be given field trials until a firm or firms of chemical manufacturers have produced it on a pilot scale and decided that it can be manufactured as a commercial proposition. Again, although a prototype machine may have been shown to fill a gap in the mechanical equipment of the farm, it cannot come into use until an engineering firm is prepared to put it into commercial production. There is a close liaison between the scientists and designers employed by industry and the research workers in the agricultural research institutes, so that any results which appear to be capable of profitable development are quickly exploited. In this relationship the National Research Development Corporation co-operates with the Council and also directly with the research institutes.

Commercial development takes time and although the results of an investigation may be reported on completion to the Improvement Councils, they are often not ready for practical use until the manufacturer advertises his product for sale.

Many of the results of the Council's research, e.g., those in the field of veterinary medicine, do not affect the farmer directly, but are used by the veterinary practitioner and the government's veterinary services. The Chief Veterinary Officer of the Ministry of Agriculture, Fisheries and Food is an *ex officio* member of the Council while other veterinarians in the government service sit on the committees and other groups concerned with animal diseases. These groups are greatly strengthened by the presence of distinguished scientists from the schools of veterinary medicine. As the work progresses, the group concerned with a particular disease is well placed to decide at what point a new treatment should be tried in the field. Such trials can be arranged through the government veterinary service, which is in close touch with veterinary practitioners. Where further help has been required, the British Veterinary Association has willingly co-operated. The research workers must, of course, be closely associated with the field trials, to give advice and, if necessary, to undertake further investigations in the laboratory on questions which arise in the field.

If the results of the field trials confirm the value of the treatment, they can be made known through the professional and scientific journals as well as through conferences and lectures attended by practising veterinarians.

Manufacturing interests are also involved in the application of veterinary research. Where a new drug or vaccine is required, the treatment cannot be applied until it is commercially produced. In such instances, the manufacturers of therapeutic substances help in the dissemination of the new knowledge through their literature and technical sales services.

What then is the function of the Improvement Councils in the application of research results? It is again that of watching carefully over the whole field of agriculture and horticulture to make sure that the application of worthwhile results is not being held up in any way. The Improvement Councils can ask for a report on the progress of the work on any problem which they consider to be of special importance to agriculture and, if the application of the results so far obtained appears to be unduly delayed, they can take steps through the advisory or veterinary services to hasten their use. The Agricultural Research Council can bring to the notice of the Improvement Councils the results of research which are being accepted too slowly. There may be good reasons for delay which lie outside the scientific field and these can be discussed and weighed by the Improvement Councils. If on balance it appears that the delay is unjustified, the Improvement Councils can take steps to overcome it.

This summary of the work of the Council is intended as an introduction appropriate to a first Annual Report. In subsequent years it is hoped to present a series of articles by experts, each of which will cover a special field of the Council's activities. In this way, over a number of years, the whole of the work of the Council will be surveyed in a condensed form suitable for general reading.

ADMINISTRATION AND FINANCE 1956-57

STAFF

At the close of the year under report there were 3,790 members of staff employed at the agricultural research institutes. Of this number 770 were in the Scientific Officer class, 544 in the Experimental Officer class and 704 in the Assistant (Scientific) class. The remainder were mainly in the executive, clerical and industrial classes. The number of staff employed in the Council's Secretariat was 74.

CHANGES IN DIRECTORSHIPS

On 1st October, 1956, Mr. F. W. Toovey was appointed Director of the Glasshouse Crops Research Institute in succession to Dr. W. F. Bewley, who retired on grounds of age.

OTHER APPOINTMENTS

Following the appointment in 1954 of Dr. Braude of the National Institute for Research in Dairying as A.R.C. Adviser on Pig Research, it was decided in 1956 to create a similar post of A.R.C. Adviser on Poultry Research and to appoint to it Dr. R. F. Gordon, Director of the Houghton Poultry Research Station. Dr. Gordon undertook these additional duties on 1st May, 1956.

HONOURS AND AWARDS

The C.B.E. was conferred by Her Majesty on Professor K. Mather, F.R.S., Honorary Director of the Council's Unit of Biometrical Genetics.

The O.B.E. was conferred by Her Majesty on Mr. T. N. Hoblyn, Assistant to the Director, East Malling Research Station.

Dr. Kenneth Smith, F.R.S., Director of the Council's Virus Research Unit, was elected a member of the Council of the Royal Society.

Dr. Robert Brown, Director of the Council's Unit of Cell Physiology, Dr. R. Markham, of the Council's Virus Research Unit and Dr. Helen K. Porter, of the Research Institute of Plant Physiology, were elected to Fellowship of the Royal Society.

Dr. W. Bolton, of the Council's Poultry Research Centre, was elected a Fellow of the Royal Society of Edinburgh.

Professor F. G. Gregory, F.R.S., Director of the Research Institute of Plant Physiology, was elected a Foreign Associate of the U.S. Academy of Sciences.

Dr. G. D. H. Bell, Director of the Plant Breeding Institute, was awarded the Research Medal of the Royal Agricultural Society of England and Mr. L. E. Rowson, of the Council's Unit of Reproductive Physiology and Biochemistry, was awarded the Thomas Baxter Prize for 1956.

MEMORIAL LECTURES

In 1956 the Secretary of the Council gave the fourth Bernard Dyer Memorial Lecture to the Society for Analytical Chemistry, choosing as his subject "The Evolution of Agricultural Research".

RESEARCH ESTABLISHMENTS

The Potato Storage Investigation team, located at the Nottingham University School of Agriculture, Sutton Bonington, which since 1946 had collaborated with the Ditton Laboratory of the Department of Scientific and Industrial Research in an investigation of the practical aspects of the storage of potatoes in buildings, was disbanded at the end of 1956. The work of the two groups had demonstrated the possibility of storing potatoes in both deep and shallow stores in this country and the conditions of temperature and ventilation required to ensure success. The knowledge gained has been disseminated in demonstrations arranged by the Agricultural Land Service of the Ministry of Agriculture, Fisheries and Food and has been described in one of the Ministry's leaflets in the Fixed Equipment of the Farm Series (Leaflet No. 24, Bulk Storage of Potatoes in Buildings), as well as in scientific papers.

For a number of years the Council has supported research under Professor C. H. Waddington, F.R.S. at Edinburgh University, on the fundamental aspects of genetics that form the scientific basis for livestock breeding. In 1956, the Council decided, with the agreement of Edinburgh University, to place this research on a more permanent footing by establishing, at the University, a Unit of Animal Genetics under the direction of Professor Waddington. This came into being in October, 1957.

VISITING GROUPS

The following Institutes received Visiting Groups during the year:—

National Institute for Research in Dairying

Hannah Dairy Research Institute

Animal Breeding Research Organisation

Welsh Plant Breeding Station.

SCIENTIFIC COMMITTEES

Following the establishment in 1954 of a Technical Committee on Pig Research with three sub-committees to give increased attention to pig research, the Council's Standing Committee on research affecting Animals reconstituted their Technical Committee on Poultry Research. This was directed to review existing research on poultry in the light of the needs of the industry and of the resources available, and to make such recommendations for further research as seemed desirable. To this end, the Technical Committee set up a series of Study Groups to examine particular aspects, such as disease, nutrition, breeding,

housing and management. Each of these Study Groups held several meetings during the year and produced an assessment of the situation within their respective fields; this formed the basis of a report which has been prepared by the Technical Committee and is now under examination.

VISITS ABROAD

During the year 1956-57, grants were made from the Council's funds to enable over 100 scientists in the agricultural research service to go abroad either to visit laboratories or to take part in conferences. The conferences which they attended included: Second World Congress on Fertility and Sterility, Italy; Seventh International Grassland Congress, New Zealand; Tenth International Entomology Congress, Canada; Soil Science Congress, France; Fifth International Congress of Animal Husbandry, Spain; International Physiology Congress, Belgium; Fourteenth International Dairy Congress, Italy.

LIAISON WITH AGRICULTURAL RESEARCH IN COLONIAL TERRITORIES

Sir William Slater, as Secretary of the Council, has continued to be Chairman of the Committee for Colonial Agriculture, Animal Health and Forestry Research, thus ensuring close liaison with agricultural research in Colonial territories.

BUILDINGS AND PROPERTY

During the year a number of major schemes were completed under the Council's post-war development programme. Special purpose glasshouses and laboratories for spray analysis and biochemical research were completed at Long Ashton Research Station. The National Institute for Research in Dairying was equipped with laboratories for isotopic and chromatographic work; an extensive reorganisation of heating and electrical services was also completed at this Institute. During the year, the large development programme begun some years previously at the Animal Virus Diseases Research Institute, Pirbright was all but completed; this Institute is concerned mainly with work on foot-and-mouth disease and, in addition to its new laboratories and cattle isolation facilities, now possesses experimental and breeding units for work on small animals; specially designed sewage disposal and treatment plants have been installed to avoid any possibility of infection spreading from animal wastes.

In 1956 construction of a Radiobiological Laboratory at the Council's Field Station, Compton, was completed. The Council received a contribution towards the cost of this laboratory from the Atomic Energy Authority; it is being used for research on the uptake of fission products by plants and animals in accordance with a programme approved by the Joint Agricultural Research Council/Medical Research Council/Development Commission Committee on the Biological Problems (non-medical) of Nuclear Physics.

The Council also completed additional laboratory and animal accommodation in the first phase of the development of research facilities for their Unit of Reproductive Physiology and Biochemistry at Cambridge. A property of approximately 500 acres, adjoining the estate occupied by the Council's Field Station at Compton, was purchased to enable the station to feed its very large animal population itself.

The major works in progress at the end of the year 1956-57 are briefly listed as follows:—

Animal Breeding Research Organisation: Laboratory for climatological studies

Hannah Dairy Research Institute: extended laboratory and animal accommodation for the Nutritional Physiology Department

Glasshouse Crops Research Institute: special purpose glasshouses

John Innes Horticultural Institution: special purpose glasshouses

National Institute for Research in Dairying: new main laboratories and extensions to the experimental dairy

National Vegetable Research Station: main laboratories

Rothamsted Experimental Station: special purpose glasshouses for the Insecticides and Entomology Departments

During the year the undermentioned projects were approved in principle, so that financial provision could be made for them in 1957-58 and in subsequent years:

Agricultural Research Council Field Station, Compton: new laboratory wing

Poultry Research Centre, Edinburgh: establishment of a Sub-Station

Virus Research Unit, Cambridge: additional laboratory block

Houghton Poultry Research Station: laboratory wing and adaptation of main building

LAND AGENCY SERVICE

On 1st April, 1956, the Council instituted a Land Agency Service under which they would receive professional advice on problems of land and estate management arising on their various properties. A private firm, Messrs. W. H. Cooke & Arkwright, was selected to provide the Service for one year in the first instance, the firm being paid a fixed fee plus travelling and other expenses. It was arranged that the Service should be made available, as required and without additional charge, to any of the grant-aided institutes in England and Wales.

AGRICULTURAL RESEARCH FUND

The greater part of the Council's expenditure is met from the Agricultural Research Fund which is financed by a Parliamentary grant in aid. In the financial year ended 31st March, 1957, gross current expenditure was £3,340,870; capital expenditure on buildings and special apparatus amounted to £504,453. A grant in aid of £3,626,000 was voted by Parliament, but of this only £3,570,000 was drawn. The grant in aid was augmented by receipts totalling £226,087 derived from sales of livestock, produce, etc., at research institutes and units, from rents and hostel charges, and from the sale of publications and reports, as well as by contributions totalling £50,022 from Government Departments and other sources. These contributions included £20,000 from the Atomic Energy Authority towards the cost of setting up the Radiobiological Laboratory at the Council's Field Station, Compton, Berkshire; £10,000 from the Animal Health Trust towards the maintenance costs of the Houghton Poultry Research Station; £8,231 from the Hops Marketing Board and the Institute of Brewing towards the cost of research on hop diseases at Wye College; £5,700 from the Colonial Office towards the cost of the work of the Council's Unit of Experimental Agronomy; £2,538 from the Colonial Office for research on insecticides at Rothamsted Experimental Station; and £2,908 from the Forestry Commission for research at Rothamsted on forest soils and the nutrition of forest trees.

The allocation under main heads of the total expenditure from the Agricultural Research Fund was as follows:—

	<i>Per cent</i>
Administration	2·7
Research institutes and units of the Council:	
Current expenditure	24·3
Capital expenditure	4·4
Special research grants	4·3
Studentships, training awards and fellowships (including travelling fellowships for visits overseas)	1·1
Grants to independent research institutes (England and Wales):	
For current expenditure	54·5
For capital expenditure	8·7
	100·0

GRANTS MADE FROM THE VOTE OF THE DEPARTMENT OF AGRICULTURE FOR SCOTLAND

Grants to the independent agricultural research institutes in Scotland are made from the Vote of the Department of Agriculture for Scotland, on the advice of the Council. For the financial year which ended on 31st March, 1957, the total of such grants was £615,725 for current expenditure and £52,522 for capital expenditure.

THE UNDERWOOD FUND

By the terms of their Charter, the Council are empowered to accept and administer private funds or properties which may be given or bequeathed to them in trust, either for the general purposes of their work or for special objects within their field.

A bequest valued at about £60,000 was received by the Council in 1949, under the will of the late Miss L. M. Underwood. This bequest has been used to establish an Underwood Fund. During the financial year 1956–57 the income of the Fund was £2,853; payments out of the Fund were £1,654. The balance on current account at 31st March, 1957, was £1,889.

This Fund has been used by the Council to provide Fellowships for distinguished overseas scientists who wish to work in this country on problems of interest to the Council.

Two awards were made in 1956–57. The first enabled Mr. M. Fieldes, of the Soil Bureau, D.S.I.R., New Zealand, to visit this country for a year to work with Dr. R. K. Schofield at the Soil Science Laboratory, Oxford University, on the mechanism of ion absorption by inorganic soil colloids. The second was a grant of £500 towards the expenses of Professor Robley Williams, Head of the Virus Laboratory at the University of California, who spent about a year at the A.R.C. Virus Research Unit, Cambridge.

During Professor Williams' stay, three papers were prepared by him jointly with Dr. Kenneth Smith, F.R.S., the Director of the unit, for publication in scientific journals.

FINANCIAL ASSISTANCE FROM OUTSIDE BODIES

The Council gratefully acknowledge the assistance received during the year from the following bodies:

(1) *W. K. Kellogg Foundation*

The Foundation once again generously made four fellowships available to the Council, thus enabling four members of staff of the institutes to spend a period working in and visiting laboratories in the United States.

The Foundation also again placed at the Council's disposal the equivalent of £1,000 in dollars to be used for the purchase in the U.S.A. of scientific equipment required at various agricultural research institutes.

(2) *The Wellcome Trust* and (3) *The Rockefeller Foundation*. Grants of £5,000 by the Wellcome Trust and of £4,900 by the Rockefeller Foundation were made to the Rowett Research Institute for the building and equipment of a special preparation room to be used for the isolation and preparation of components of microbial, plant and animal materials for further identification, analyses and *in vivo* testing.

ROTHSCHILD

Chairman of the Agricultural Research Council

W. K. SLATER

Secretary of the Council

Cunard Building,

15, Regent Street,

London, S.W.1

18th March, 1958.

RESEARCH STUDENTSHIPS AND FELLOWSHIPS

(a) *Research studentships*

To maintain an efficient and progressive agricultural research service, it is essential to attract graduate recruits of a high standard. Honours graduates in one of the basic sciences are, however, rarely qualified to undertake agricultural research without additional training. Some may require a further period of systematic study in another science, e.g. a botanist proposing to work on plant physiology may require training in biochemistry; all will need training in research methods.

Before 1946, the agricultural research studentship scheme was administered by the two Agricultural Departments, the Council advising the Departments on the selection of candidates. After the war, the Council took over full responsibility for the scheme and the number of awards was increased, until now some 30 of them, tenable up to three years, are offered each year. Over 300 studentships and training grants have been awarded since 1946.

Although students holding these awards are under no obligation to undertake agricultural research at the end of their period of post-graduate training, it is worth mentioning that, since 1932, nearly 40 per cent of the recipients have been recruited into the agricultural research service or the advisory services, while some 20 per cent secured University appointments.

The following awards were made in 1956:

<i>Name</i>		<i>Place of Tenure</i>	<i>Subject</i>
M. M. Allen ...	...	National Institute for Research in Dairying.	Pig Nutrition
J. H. Anderson	...	Aberdeen University ...	Soil Bacteriology
C. F. Arlett ...	...	Birmingham University ...	Cytogenetics
T. Bauchop ...	...	Sheffield University ...	Chemical Microbiology
W. F. Bodmer...	...	Cambridge University ...	Genetics
P. R. Carnegie	...	Rowett Research Institute ...	Biochemistry
R. G. Dalton ...	...	Glasgow University ...	Animal Pathology
P. S. Dawson ...	...	Edinburgh University...	Veterinary Training Grant
A. K. Entwistle	...	Cambridge University ...	Veterinary Training Grant
A. J. Gibbs ...	...	Rothamsted Experimental Station.	Plant Virology
J. F. D. Greenhalgh ...	...	Rowett Research Institute ...	Animal Nutrition
R. M. Macrae...	...	Edinburgh University...	Soil Bacteriology
B. Mitchell ...	...	National Vegetable Research Station.	Entomology
J. Moorby ...	...	Manchester University ...	Plant Physiology
A. J. Peel ...	...	Nottingham University ...	Plant Physiology
J. F. Pennock ...	...	Liverpool University ...	Biochemistry
D. A. Perry ...	...	Rothamsted Experimental Station.	Plant Pathology
C. J. Randall ...	...	Cambridge University ...	Veterinary Training Grant
C. H. F. Rowell	...	Cambridge University ...	Ornithology

<i>Name</i>	<i>Place of Tenure</i>	<i>Subject</i>
G. R. Sagar	Oxford University	Grassland Agronomy
T. A. Smith	Birmingham University	Plant Physiology
A. South	London University	Entomology
D. C. Taylor	Glasgow University	Animal Pathology
I. H. Tyson	University College, Aberystwyth.	Plant Breeding
T. B. Wadsworth	Cambridge University	Insect Physiology
D. I. Wallis	Cambridge University	Insect Behaviour
T. C. Wignall	Cambridge University	Statistics
P. C. Williams	University College, Aberystwyth.	Plant Biochemistry
H. C. Wilson	Glasgow University	Animal Pathology
D. A. B. Young	Oxford University	Biochemistry

At 31st March, 1957 the number of students in training was 70, divided amongst the different disciplines as follows:—

<i>Botany</i>	<i>Chemistry</i>	<i>Entomology</i>	<i>Zoology and Veterinary Science</i>	<i>Statistics</i>
21	21	10	17	1

(b) *Fellowships*

Junior Agricultural Research Fellowships were first offered by the Council in 1950 to provide opportunities for young research workers of outstanding ability to undertake independent research before seeking an appointment in a research institute or elsewhere. Up to three of these awards, tenable for a maximum period of three years, are available annually; to date, nine Fellowships have been granted. The Fellowships current at 31st March, 1957 were:—

P. Andrews, B.Sc., Ph.D. ...	Bristol University ...	A study of the biosynthesis of certain plant polysaccharides.
J. G. Shoesmith, B.Sc., Ph.D.	Manchester University	Research on the biochemical aspects of bacterial motility.
W. D. Stein, M.Sc.	London University ...	Research on the mechanism of facilitated diffusion in the red blood cell.

In 1952, another type of award was introduced—the Veterinary Research Fellowship—which is designed to enable veterinary graduates to continue their postgraduate researches for a further period of up to three years before seeking a post.

The following Veterinary Research Fellowships were held at 31st March, 1957:—

A. C. Palmer, B.A., M.R.C.V.S.	School of Veterinary Medicine, Cambridge.	Research on scrapie disease of sheep.
J. M. Payne, B.Sc., Ph.D., M.R.C.V.S.	University College Hospital Medical School.	Research on enzootic abortion.

SPECIAL RESEARCH GRANTS

The Council sets aside each year a substantial sum of money for the provision of special research grants. During the current year this amounted to £187,500. In the main the grants were made to University Departments to provide funds for the initiation or development of promising lines of research on subjects of interest to the Council.

Grants are normally limited to three years, in order to ensure that money is available each year to assist new research projects. Occasionally, however, where it is clear at the outset that continuous work for a longer period is essential, the Council makes a grant on a five-year basis.

The Council's grants are not intended to defray the ordinary running costs of the laboratory to which they are made, nor to provide equipment which could reasonably be expected to form part of the normal facilities of such a laboratory. For the most part the grants are used to enable the recipient body to employ graduate (or other) assistance and to meet special expenses incidental to the investigation.

Applications for these grants are received throughout the year and are dealt with by the Secretary, or in his absence by the Deputy Secretary, on behalf of the Council in accordance with the advice of the appropriate Standing Committee. Where it appears that there would be serious disadvantage in delaying an application for consideration at the next meeting of the relevant Standing Committee, the Secretary, or where necessary the Deputy Secretary, have been empowered by the Council to make or renew grants at their discretion after taking such advice as seems to them appropriate. All decisions concerning grants, whether taken on the advice of a Standing Committee or otherwise, are reported to the Council at its next meeting. In doubtful cases the Standing Committee or the Secretary may decide that the Council's approval should be obtained before the grant is made or rejected.

The grants current on 31st March, 1957, were as follows:—

1. ABERDEEN UNIVERSITY

(i) *Department of Biological Chemistry*

- (a) Metabolism of nitrifying bacteria.
- (b) Phospholipase D of plant tissues.

(ii) *Department of Soil Science*

Variations in soil structure throughout a ley farming rotation, with special reference to the effect of grasses and their treatment.

2. ABERYSTWYTH, UNIVERSITY COLLEGE OF NORTH WALES

Department of Agricultural Botany

Cytogenetical and ecological studies of plants of economic importance.

3. BANGOR, UNIVERSITY COLLEGE OF NORTH WALES

(i) *Department of Agricultural Botany*

Mineral nutrition of certain races of wild white clover.

(ii) *Department of Agricultural Chemistry*

- (a) Bracken poisoning.
- (b) Biochemical and nutritive properties of pasture. (A five-year block grant).

(iii) *Department of Chemistry*

Disproportionating enzyme (D-enzyme) of plants.

4. BIRMINGHAM UNIVERSITY

(i) *Department of Anatomy*

Presumed nervous control of anterior pituitary gland.

(ii) *Department of Botany*

Inheritance of frost resistance in the potato.

5. BRISTOL UNIVERSITY

Department of Physiology

(a) Effect of oestrogen on the adrenal cortex.

(b) Bovine acetonaemia.

6. CAMBRIDGE UNIVERSITY

(i) *School of Agriculture*

(a) Resistance of *Solanum andigenum* to potato root eelworm.

(b) Continuous field drain laying.

(c) Fertility in sheep.

(d) Carcass quality of beef.

(ii) *Department of Animal Pathology*

Respiratory diseases in poultry.

(iii) *Department of Biochemistry*

(a) Effect of growth hormone and insulin on farm animals.

(b) Biochemistry of the uterus.

(iv) *Botany School*

(a) Studies of Photosynthesis.

(b) Nature and origin of physiologic races in *Phytophthora infestans*.

(v) *Cavendish Laboratory*

Maintenance and operation of the Siemens Electron Microscope.

(vi) *Molteno Institute*

Comparative physiology of parasitic protozoa and helminths.

(vii) *Department of Pathology*

(a) Immunology and serology. (A five-year block grant made jointly with the Nuffield Foundation).

(b) Blood groups of the pig.

(viii) *Department of Veterinary Clinical Studies*

(a) Action of ganglionic blocking agents on animals under conditions of anaesthesia.

(b) Reservoirs of ringworm infection.

(c) Variations with time, diet and breed in the principal inorganic constituents of bovine blood.

(d) Scrapie in sheep.

(e) Neonatal mortality and haemolytic disease in pigs.

(ix) *Department of Zoology (Veterinary Anatomy)*

Role of the central nervous system and endocrine glands in regulation of female reproduction organs.

7. DURHAM UNIVERSITY (KINGS COLLEGE)

School of Agriculture

Internal parasites in sheep.

8. EDINBURGH UNIVERSITY

- (i) *Departments of Agriculture and Chemistry*
Grass conservation. (A five-year block grant).
- (ii) *Department of Animal Genetics*
 - (a) Animal Genetics. (A five-year block grant).
 - (b) Genetics of beef and milk production in dual purpose cattle.
- (iii) *Department of Zoology*
Embryonic endocrinology of insects.
- (iv) *Heriot-Watt College: Department of Chemistry*
Anthelmintics.

9. GLASGOW UNIVERSITY

- (i) *Department of Botany*
The extent of translocation of growth-regulating compounds into the rhizome of bracken.
- (ii) *Veterinary School*
 - (a) Immunological and biochemical studies of helminth diseases.
 - (b) Piglet anaemia.
 - (c) Johne's disease.
 - (d) Relationship of the feeding and management of sows to the health and survival rate of litters.
 - (e) Pathology of pneumonia in pigs.
- (iii) *Department of Zoology*
Midgut, peritrophic membrane and the enteric caeca in Diptera (Cyclorhapha).

10. HARPER ADAMS AGRICULTURAL COLLEGE

- (a) Poultry husbandry investigations.
- (b) Pig husbandry investigations.

11. LEEDS UNIVERSITY

- (i) *Department of Bacteriology*
Passage of antitoxins into the rabbit foetus.
- (ii) *Department of Biochemistry*
Insect biochemistry.
- (iii) *Department of Botany, sub-Department of Biophysics*
An investigation of the structure of the cell wall of apple fruit and of the effects on the apple tree of "rubbery wood" virus infection. (In collaboration with East Malling Research Station).
- (iv) *Dental School and Hospital*
Effects of fluorine on bone metabolism.

12. LIVERPOOL UNIVERSITY

- (i) *Department of Biochemistry*
 - (a) Study of some aspects of the biochemistry of pregnant and lactating cows.
 - (b) Biosynthesis of riboflavin.
- (ii) *Department of Veterinary Preventive Medicine*
 - (a) Motor activities of the ruminant stomach.
 - (b) Coccidiosis in turkeys.
 - (c) Respiratory diseases of poultry.
- (iii) *Department of Zoology*
Comparative endocrinology.

13. LONDON UNIVERSITY

BIRKBECK COLLEGE

Department of Physics

Molecular structure of viruses.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

(i) *Department of Botany*

(a) Research on interactions between organisms in the rhizosphere of oats and barley.

(b) Fat production by fungi in culture on artificial media.

(ii) *Research Institute of Plant Physiology*

(a) Bulbing of onions.

(b) Effects of nitrogen nutrition on starch metabolism in tobacco leaf discs.

(iii) *Department of Zoology and Applied Entomology*

Insect ecology.

KING'S COLLEGE

(i) *Department of Botany*

(a) Fate of indole-3-acetic acid and related substances in metabolism and growth of cereal seedlings.

(b) Mechanism of action of indolyl-acetic acid and related growth substances.

(ii) *Department of Zoology*

Research on inheritance mechanisms in protozoa.

LISTER INSTITUTE OF PREVENTIVE MEDICINE

(a) Mechanism of starch-carbohydrase action.

(b) Research on protozoa.

LONDON HOSPITAL MEDICAL COLLEGE

Department of Biochemistry

Study of electrophoretically distinct haemoglobins in the blood of sheep.

POSTGRADUATE MEDICAL SCHOOL

Urinary steroids of farm animals.

ROYAL VETERINARY COLLEGE

(a) Calf diseases (joint investigations with National Institute for Research in Dairying).

(b) Extrachromosomal influences in development and heredity.

UNIVERSITY COLLEGE

(i) *Department of Anatomy*

Perfusion *in vitro* of the pregnant uterus.

(ii) *Department of Biochemistry*

Biochemistry of lactation.

(iii) *Department of Biometry*

(a) Genetics and cytology of European newts.

(b) Parthenogenesis in *Lebistes reticulatus*.

(c) The genetics of developmental rate in *Drosophila subobscura*.

- (iv) *Department of Zoology*
(a) Investigation of the viruses carried by British mosquitoes.
(b) The phenomena of acquired tolerance of tissue grafts.
(c) Cytological effect of inbreeding in *Drosophila*.

UNIVERSITY COLLEGE HOSPITAL MEDICAL SCHOOL

Department of Clinical Pathology

The metabolism of diaminopimelic acid in micro-organisms.

WYE COLLEGE

Poultry breeding. (A long-term grant).

14. MANCHESTER UNIVERSITY

Department of Botany

Cytogenetical investigations on soft fruits. (A five-year block grant).

15. MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

- (i) *National Agricultural Advisory Service: Eastern Province*
Wheat bulb fly.
- (ii) *Veterinary Laboratory, Weybridge*
(a) Nature, significance and genetic character of *Brucella* variants.
(b) Survey of the incidence of losses from diseases in dairy cattle.

16. NATIONAL VEGETABLE RESEARCH STATION

Didymella disease of outdoor tomatoes.

17. NORTH OF SCOTLAND COLLEGE OF AGRICULTURE

Control of gangrene in potatoes.

18. NOTTINGHAM UNIVERSITY

- (i) *Department of Agriculture (in collaboration with A.R.C. Unit of Plant Cell Physiology)*
Germination of *Orobanche*.
- (ii) *Department of Agricultural Chemistry*
Factors influencing the spread of aphids within the potato crop.
- (iii) *Department of Horticulture*
(a) Water relationships of plants growing under glass, with special reference to the tomato.
(b) Propagation of plants from root cuttings.

19. OXFORD UNIVERSITY

- (i) *Department of Agriculture*
(a) Use of photogrammetric methods for the classification and evaluation of soils and land class units.
(b) Revision of the Soil Survey Field Handbook.
(c) Studies of the uptake of fission products by plants and of the mechanism of radiation damage in plant tissues.
- (ii) *Department of Biochemistry*
Fractionation and characterisation of β -lactoglobulin.
- (iii) *Department of Zoology*
(a) Genetics of polyhedral virus disease in insects and studies of non-genic determinants in inheritance.
(b) The mechanism of secretion of exoskeletal material of insects, in particular the biosynthesis of chitin.

20. READING UNIVERSITY

- (i) *Department of Agriculture*
Poultry husbandry investigations.
- (ii) *Department of Agricultural Chemistry*
Study of the hen egg shell.
- (iii) *Department of Horticulture*
Developmental physiology of carnations, including factors affecting flowering.
- (iv) *Department of Microbiology*
 - (a) Nutrition and metabolism of pleuropneumonia-like organisms.
 - (b) Serology of streptococci.

21. ROTHAMSTED EXPERIMENTAL STATION

- (a) Rental and maintenance of electronic computer in the Statistical Department.
- (b) Insecticide investigations. (The money for this grant is provided by the Colonial Office).
- (c) Nutrition of forest trees in nurseries. (The money for this grant is provided by the Forestry Commission).

22. SHEFFIELD UNIVERSITY

- (i) *Departments of Biochemistry and Microbiology (and A.R.C. Unit of Microbiology)*
Bacterial photosynthesis.
- (ii) *Department of Genetics*
Developmental stability in the individual.

23. UNIVERSITY COLLEGE OF SWANSEA

Department of Botany
Verticillium wilt of lucerne and brussels sprouts.

24. OTHER ORGANISATIONS AND INDIVIDUALS

- (i) *British Field Products Ltd.*
Lucerne investigations.
- (ii) *Electrical Research Association*
 - (a) Crop conservation and storage.
 - (b) Farm machinery and equipment.
 - (c) Electricity in livestock husbandry.
 - (d) Electricity in horticulture.
 - (e) Other specialised applications of electricity.
- (iii) *The Polytechnic, London*
Biological control of eelworms by means of predacious fungi.
- (iv) *Private A.I. Centres Group*
Infertility in cattle.
- (v) *C. B. Williams, M.A., Sc.D., F.R.S.*
Relation of weather conditions to insect activity and insect populations.

REPORTS FROM AGRICULTURAL RESEARCH INSTITUTES AND UNITS

The work of each institute and unit during the year under review is described briefly in the reports which follow. These have been prepared by the individual Directors and are arranged under subject headings.

To avoid increasing unduly the size of the Council's report, lists of papers published during the year have been excluded. Reference to these will be found in the Annual Reports of the different institutes; where no printed report is issued, lists of published papers may be obtained on direct application to the institute or unit concerned.

SOIL

ROTHAMSTED EXPERIMENTAL STATION

Harpenden, Herts.

Director: SIR WILLIAM G. OGG, M.A., B.Sc., Ph.D., LL.D., F.R.S.E.

Deputy Directors: F. C. Bawden, M.A., F.R.S. (Plant Pathology Division)
A. Muir, Ph.D. (Soils Division)

PHYSICS

Head of Department: H. L. Penman,
M.Sc., Ph.D., F.Inst.P.

G. H. Cashen, M.Sc.
W. W. Emerson, B.A., Ph.D.

CHEMISTRY

Head of Department: G. W. Cooke,
Ph.D., F.R.I.C.

P. W. Arnold, M.A., Ph.D.
J. M. Bremner, Ph.D.
Miss S. G. Heintze, M.Phil.
G. E. G. Mattingly, Ph.D.
K. Shaw, B.Sc.
O. Talibudeen, M.Sc., Ph.D.
R. G. Warren, B.Sc.

PEDOLOGY

Head of Department: A. Muir, Ph.D.

C. Bloomfield, Ph.D., F.R.I.C.
G. Brown, B.Sc.
R. Greene-Kelly, Ph.D.
D. M. C. MacEwan, M.A., Ph.D.
I. Stephen, Ph.D.

TROPICAL SOILS ADVISER

H. Greene, D.Sc.

SOIL MICROBIOLOGY

Head of Department: H. G. Thornton,
B.A., D.Sc., F.R.S.

Mrs. J. Kleczkowska, Ph.D.
Miss J. Meiklejohn, Ph.D.
P. S. Nutman, Ph.D.
F. A. Skinner, M.A., Ph.D.
N. Walker, Ph.D., F.R.I.C.

BOTANY

Head of Department: D. J. Watson, Ph.D.

E. C. Humphries, D.Sc.
P. C. Owen, Ph.D.
Miss J. M. Thurston, B.Sc.
Miss K. Warington, D.Sc.

BIOCHEMISTRY

Head of Department: N. W. Pirie,
M.A., F.R.S.

Miss M. Holden, B.Sc.
R. H. Kenten, B.Sc.
P. J. G. Mann, Ph.D.
M. V. Tracey, M.A.
G. H. Wiltshire, Ph.D.

STATISTICS

Head of Department: F. Yates,
Sc.D., F.R.S.

D. A. Boyd, Ph.D.
B. M. Church, B.Sc.
M. J. R. Healy, B.A.
F. B. Leech, B.Agr., M.R.C.V.S.
H. D. Patterson, M.Sc.
D. H. Rees, B.Sc.
M. H. Westmacott, B.A.

INSECTICIDES AND FUNGICIDES

Head of Department: C. Potter,
D.Sc., D.I.C.

P. E. Burt, B.A.
M. Elliott, Ph.D.
K. A. Lord, M.A., Ph.D., A.R.I.C.
A. H. McIntosh, Ph.D., A.R.I.C.
J. Ward, B.Sc.
M. J. Way, M.A.

PLANT PATHOLOGY

Head of Department: F. C. Bawden,
M.A., F.R.S.

S. N. Adams, D.Phil.
J. W. Blencowe, Ph.D.
L. Broadbent, Ph.D.
E. W. Buxton, Ph.D.
L. F. Gates, B.A.
Miss M. D. Glynné, D.Sc.
J. M. Hirst, Ph.D.
R. Hull, Ph.D.
B. Kassanis, D.Sc.
A. Klecskowski, M.D., Ph.D.
I. Macfarlane, B.Sc.
H. L. Nixon, M.A.
G. A. Salt, M.A., Ph.D.
T. W. Tinsley, Ph.D.
Mrs. M. A. Watson, Ph.D.

ENTOMOLOGY

Head of Department: K. Mellanby,
C.B.E., B.A., Sc.D.

C. J. Banks, Ph.D.
H. F. Barnes, M.A., Ph.D.
C. G. Johnson, D.Sc., Ph.D.
D. B. Long, M.A., Ph.D.
P. W. Murphy, B.Agr.Sc., D.Phil.
F. Raw, Ph.D.

NEMATODOLOGY

Head of Department: F. G. W. Jones, M.A.

D. W. Fenwick, D.Sc.
Miss M. T. Franklin, Ph.D.
J. B. Goodey, Ph.D.
H. R. Wallace, B.Sc., Ph.D.

BEE RESEARCH

Head of Department: C. G. Butler, Ph.D.

L. Bailey, M.A., Ph.D.
J. Simpson, B.A., Ph.D.

FIELD EXPERIMENTS

Head of Section: H. V. Garner, M.A., B.Sc.
G. V. Dyke, M.A.

ROTHAMSTED AND WOBURN FARMS

Head of Farms: J. R. Moffatt,
B.Sc.(Agric.), N.D.A., A.I.B.A.E.

WOBURN EXPERIMENTAL STATION

Officer in Charge: C. A. Thorold,
M.A., A.I.C.T.A.

Secretary: J. B. Bennett, A.C.A.

Librarian: D. H. Boalch, M.A.

Rothamsted Experimental Station is the oldest agricultural research station in the world. It was founded in 1843 by Sir John Bennet Lawes, who during his lifetime maintained the station at his own expense and in 1889 provided an endowment for its continuance. In 1911 the Development Commissioners made their first grant to the Station. Since then Government grants have been made annually and at the present time the bulk of the funds is provided through the Council.

Since the end of the war there has been a very great expansion and the staff has trebled since 1943. Departments of Pedology, Bee Research, Biochemistry and Nematology have been added since that date; in addition, Rothamsted has become the headquarters of the Soil Survey of England and Wales. The problem of accommodation for this rapidly expanding staff has been met to some extent by adaptation of existing buildings and by the provision of part of a new laboratory block which will eventually accommodate the whole of the plant pathology division.

The work of the station falls into two main divisions, (a) soils and crop nutrition, and (b) plant pathology. There are also departments of Statistics (including a Statistical Research Service), of Biochemistry and of Bee Research.

On 31st March, 1957, the scientific and experimental staff of the Station numbered 166.

CURRENT WORK AND OUTCOME OF RESEARCH

Pedology

The aim of this department is to elucidate the genesis and development of soils and to attain a better understanding of soil properties. Studies are being made of the soil parent materials and of the changes that occur in the processes of weathering, much attention being given to clay minerals and hydrous oxides since the nature and amounts of these determine many of the properties of soils, for instance, the fixation of potash and phosphate. The technique of

x-ray diffraction and other physical methods are being used extensively in this work. Particular attention is also being given to the translocation of iron and aluminium compounds, since the processes by which these are mobilised, transported and redeposited are of fundamental importance in soil genesis and classification, and these studies find practical application in soil surveys. The availability of phosphorus to plants is also strongly influenced by the presence of ferric and aluminium sesquioxides, which probably affect the availability of certain important trace elements.

Chemistry

This department is concerned chiefly with the use of manures and fertilisers, and many of the investigations are based on field and pot experiments. An extensive programme, now nearing completion, on the placement of fertilisers with or alongside the seed has given results of great practical importance. Nitrogen fertilisers, including some not yet in general use, are being compared on a variety of soils and crops, and studies are being made of the effect of rates and times of application to spring-sown cereals on quality of barley. Other work includes investigations on soil organic matter, the availability of nitrogen and phosphorus compounds in the soil and the manuring of seedling forest trees in nurseries. Radio-isotopes are being used to obtain improved chemical measurements of the amounts of phosphorus which soils can supply to crops.

Physics

There are two main branches of work in this department, soil physics and agricultural meteorology. The results of studies of surface properties of clay are being used in work on soil structure and on the way in which the structure is dependent on organic matter. A permeability test devised in the department has shown the improvement in structure under a ley, but so far, the farming benefit of the improvement has not been clearly established.

On the meteorological side, micro-climate records in potatoes and wheat have been obtained in detail more than adequate for studies of pests and diseases, and suitable for ultimate analysis in terms of water and energy needs of field crops. A special transpiration gauge, built by the National Institute of Agricultural Engineering, gives a continuous record of water use by a crop in the field. Previous work on transpiration is now being exploited in an experiment that is demonstrating that irrigation can increase crop yields, and, in collaboration with the Meteorological Office, guidance is being given to farmers who use irrigation.

Soil Microbiology

Current investigations in the department concern the soil nitrogen cycle, various aspects of soil micro-ecology and the anaerobic decomposition of cellulose relating to the fermentative production of power gas. The ecological work includes studies on rhizosphere bacteria resistant to antibiotics; the microbial colonization of partially sterilised soil; the nature of soil fungistatic activity; the ecology of herbicide disappearance in soil; and an examination of the effect of the soil microfauna upon the microflora. The fungistatic work bears upon control of soil-borne disease. Nitrogen cycle investigations include studies on the activity and distribution of free-living nitrogen-fixing organisms and on nitrification. In the field of symbiotic fixation, bacteriophage-induced variation in nodule bacteria is under examination together with genetic studies on variation in the legume host; these studies have as their object the elucidation of the physiology of infection and certain biochemical activities associated with nitrogen fixation. Much of the department's work has had a practical bearing on the seed inoculation of legumes.

Botany

Studies carried out in this department concern the ecology of weeds, especially wild oats, various problems in plant nutrition, the effect of virus infection on the physiology of the host plant, and the physiological basis of variation in yield. The number of viable wild oats seeds in infested land sown to temporary ley decreased only slightly in the third year, suggesting that a ley may be ineffective in eradicating wild oats. Nutritional studies have been made on the interaction between molybdenum and iron, the use of chelated complexes as sources of iron, and the effect of excising parts of the root system on subsequent nutrient uptake and growth. The causes of differences in grain yield between barley varieties, the dependence of growth and yield on soil moisture content, the effects of varied nutrient supply on leaf growth, and the dependence of crop yield on leaf area index are also being investigated.

Plant Pathology

Diseases of crop plants caused by viruses and fungi are the subjects of study in this department. Several viruses have been shown to be nucleoproteins and much work is done on the constitution, properties and behaviour of viruses. The manner in which they are perpetuated and spread, and the factors that affect the susceptibility of plants to infection, are also major lines of work, from which methods have been developed for producing virus-free lines of clonal varieties and for decreasing the incidence of important diseases in crops as diverse as potato, sugar beet, lettuce and cauliflower.

Much of the work on fungus diseases is also ecological and epidemiological, and aims to discover how the fungi survive between susceptible crops and what conditions allow them to increase dangerously. From this work, crop rotations and other cultural practices have been discovered that control root-rots of cereals, and methods for forecasting the need to spray against air-borne pathogens have been improved.

Nematology

The department studies those nematodes or eelworms which are important as plant pests in agriculture and horticulture. Injurious species are received for identification from Great Britain, other Commonwealth countries and Colonial Territories, and those new to science are described. The research work includes study of the life history of parasites, the range of host-crops and weeds which a given species will attack, the degrees of resistance shown by different varieties of a host species and the complex interaction between parasite and host. All these topics have a bearing on control. Much time has been devoted to cyst-forming nematodes which are important pests of field crops in Great Britain. Work has recently begun on migratory soil nematodes and on these soil conditions which influence the activity of nematodes parasitic on roots.

Insecticides and Fungicides

The laboratory work of the department consists chiefly of studies on the physico-chemical and biological factors influencing the toxicity of insecticides and fungicides, and on their biochemical and physiological mode of action. In addition, apparatus and techniques for the precise estimation of toxicity are being elaborated. These laboratory studies have practical value because the information they give is essential if pest control chemicals are to be used intelligently, and to the best advantage, and because the information helps in the search for new and better chemicals.

The field work is concerned with the control of some important pests of British agriculture, wireworms, black bean aphid, wheat bulb fly and the transmitters of potato viruses. Amongst the practical results of this work are an

economical method of control of black aphid on field beans and advances in the control of virus spread in potatoes.

Entomology

The work of the department is devoted mainly to fundamental problems of entomological research, particularly those relating to insects of agricultural importance. These studies include the effects of climatic factors on insect physiology, particularly as they relate to acclimatization, insect dispersal and the way in which pests find crops. The morphology and physiology of pest insects, including gall midges, aphids and the wheat bulb fly are also being investigated. Experiments have been carried out in several areas on the importance of earthworms, insects and mites in maintaining and improving soil fertility. This work should soon enable practical advice to be given, especially to those reclaiming marginal land.

Biochemistry

The study of plant proteins is, broadly, the main work of this department. Some of the proteins are enzymes—amine oxidase, peroxidase, polyphosphatase, ribonuclease and thiaminase. They are concerned with problems as diverse as alkaloid synthesis, the infectivity of viruses, and bracken poisoning. Other proteins are of interest as viruses or non-infective companions of viruses, and as microsomes or mitochondria carrying integrated parts of the plant's enzyme mechanism. Research is also being done on the chemical nature of some fungal components that may play a part in the formation of soil organic matter, and the potato root eelworm hatching factor is being investigated. The extraction of protein as an economical source of food, for non-ruminant animals and man, is also being studied and this process is now being done on a pilot plant scale.

Bee Research

The department studies both the healthy and the diseased honeybee and the pollination by honeybees and other insects of important fruit and seed crops. Considerable advances have been made in our knowledge of the biology of the organisms responsible for two serious diseases of the honeybee—Nosema disease and European Foul Brood disease. The organisms which induce the latter disease have been identified and cultured for the first time. The work on Nosema has already led to the development of a very effective and economical method of treatment of infested colonies. Progress has also been made on studies on the social organisation of the honeybee community, and it has been shown that much of this organisation is controlled by the distribution amongst the worker bees of a substance obtained from their queen. This information is leading to greater understanding of such problems of practical beekeeping as swarming, queen superseding and queen introduction.

Statistics

This department is concerned with the design of field and laboratory experiments and the analysis of the results, the planning and analysis of field surveys and the many and varied statistical problems that arise in agricultural and biological research. It also conducts operational research studies on the application of the results of such research under practical farming conditions. The department acts as a central statistical unit which can assist other research stations, both in this country and overseas, and the National Agricultural Advisory Service as required. An electronic computer was installed in 1954 and the department has been very actively engaged in developing its use in research statistics. It has already been successful in making available a computing service for many of the standard statistical analyses which were previously carried out on desk machines, and is rapidly developing methods of analysis which have till now been impracticable owing to the excessive computational labour involved.

Farms

The farms, consisting of 600 acres of heavy soil at Rothamsted and 130 acres of light soil at Woburn, are entirely devoted to experiments so far as the land is suitable.

Some 3,000 plots are set out each year by the farm staff and the *Field Experiments* Section. There are three main types of experiments:—

- (a) the classical experiments of Lawes and Gilbert, whose cropping and treatments have been practically unchanged since the foundation of the Station in 1843;
- (b) long-period rotation experiments of modern statistical design, the oldest of which have been running for nearly 30 years. These study the slow changes in soil fertility brought about by different farming systems;
- (c) short-term experiments, repeated also at outside centres, in which first-year effects are the main consideration.

Most of the experiments are concerned with plant nutrition, but an increasing number are designed to study plant pathology problems in the field.

A comprehensive Annual Report is published giving a detailed account of the work of the different departments and summaries of the publications issued during the year.

THE MACAULAY INSTITUTE FOR SOIL RESEARCH Craigiebuckler, Aberdeen

Director: D. N. McARTHUR, C.B.E., D.SC., PH.D., F.R.I.C., F.R.S.E.

Deputy Director: R. L. Mitchell, B.SC., PH.D., F.R.I.C., F.R.S.E.

PEDOLOGY

Head of Department: Vacant

R. C. Mackenzie, B.SC., PH.D., A.R.I.C.

B. D. Mitchell, B.SC.

W. A. Mitchell, B.SC.

R. A. Robertson, B.SC.

and Officers of the Soil Survey (Scotland)

SPECTROCHEMISTRY

Head of Department: R. L. Mitchell,
B.SC., PH.D., F.R.I.C., F.R.S.E.

V. C. Farmer, B.SC., PH.D.

R. O. Scott, B.SC., PH.D., A.R.I.C., A.R.T.C.

D. J. Swaine, M.SC., PH.D., F.R.A.C.I.

A. M. Ure, B.SC., PH.D.

BIOCHEMISTRY

Head of Department: J. S. D. Bacon,
M.A., PH.D.

R. B. Duff, B.SC., PH.D.

R. I. Morrison, B.SC., PH.D., A.R.I.C.

PLANT PHYSIOLOGY

Head of Department: P. C. de Kock,
M.SC., D.Phil.(Oxon.)

W. M. Crooke, B.SC., PH.D., A.R.I.C.

A. H. Knight, B.SC., A.R.I.C.

SOIL FERTILITY

Head of Department: E. G. Williams,
B.SC., PH.D.

G. Anderson, B.SC., PH.D.
J. W. S. Reith, B.SC.(Agr.), PH.D., A.R.I.C.

MICROBIOLOGY

Officer in Charge: D. M. Webley,
M.SC., PH.D.

FOREST SOILS

Officer in Charge: T. W. Wright,
B.SC.(For.), PH.D.

STATISTICS

Officer in Charge: R. H. E. Inkson,
B.SC., F.R.S.S.

Secretary: Miss E. J. Dey
Librarian: Miss A. M. B. Geddes,
M.A., F.L.A.

The Institute was founded in 1930 by the initial benefaction of the late Dr. T. B. Macaulay, Montreal, Canada, for the establishment of a station to be devoted to soil research and especially to research on peat, moorland and heath soils. In pursuance of the testator's wishes the investigations pursued have covered diverse branches of soil science all of which contribute to the ultimate aim of the research programme—the maintenance and improvement of soil fertility.

After the Second World War expansion led to the erection of temporary buildings to accommodate the departments of soil fertility, soil survey, plant physiology, forest soils and microbiology. With the erection of these buildings it was possible to expand, within the original station, the department of spectrochemistry. Even with this additional space the need for an entirely new Institute has long been realised, but only recently has erection been approved. The detailed plans for this new station are now in preparation.

The work of the Institute is at present organised in five major departments—Pedology, Spectrochemistry, Biochemistry, Plant Physiology, and Soil Fertility—and three sections dealing with microbiology, forest soils and statistics.

On the 31st March, 1957, there were sixty-three scientific and experimental staff at the Institute.

CURRENT WORK

The department of Pedology comprises sections dealing with soil geology and mineralogy, physical chemistry and peat ecology. It is also responsible for the soil survey of Scotland (reference to which is made under “Soil Survey of Great Britain”).

The sections dealing with Soil Geology and Mineralogy and with Physical Chemistry carry out fundamental studies on the various types of mineral and organic soils together with a detailed study of the parent clay minerals by x-ray and differential thermal analyses. The Institute has pioneered in such work and has advanced our knowledge of the parent materials upon which the fertility of our soils depend in large measure. Studies are in progress upon the interaction between clay minerals and phosphate and upon the clay-organic complex.

The peaty moorlands and heath soils form the special study of the Peat Ecology Section of the Pedology department. The Moss Survey Group of The Secretary of State's Scottish Peat Committee, of which the Director is Chairman, is co-ordinating the work being done by various organisations upon the organic soils in Scotland with special reference to possible utilisation or reclamation.

The Institute has specialised in the detection and estimation of trace elements in rocks, soils, plants and animal tissues and the department of Spectrochemistry is one of the best equipped centres for such work. Three main topics have been investigated—(a) the application of existing spectrochemical methods to the estimation of the biologically important trace elements in soils and plants, (b) the development of methods, and (c) the use of infra-red and ultra-violet absorption spectrophotometry in the identification or characterisation of materials separated in the course of the biochemical and microbiological work of the Institute.

The new department of Biochemistry is collaborating with the Plant Physiology and Soil Fertility departments and with the Microbiology section in work on the organic acids and amino acids of plants and the carbohydrates produced by various soil organisms. The study of lignin has proved to be informative as regards the differing botanical origins of peat and changes which lignin undergoes through the action of fungi upon it. In addition an assay of enzymes in plant material and a study of the biochemistry of grasses have been started.

The relationship which exists between elements in plant leaves and the correlation with the organic and amino acid content of leaves have formed one of the major topics of the department of Plant Physiology. Studies on respiration show the sensitivity to respiratory inhibitors and the effect of “respiration rate” in leaves when ratios of mineral elements such as phosphorus, iron, calcium and potassium are varied. Studies on plant tissues at cellular level have been made to investigate the morphological changes occurring in iron-deficient and iron-toxic states. In such investigations much help is obtained by the use of radioactive tracers which have also been used in collaboration with the Hill Farming

Research Organisation in the study of the root systems of plants growing on peat.

Microbiological work is principally concerned with (a) the nutrition and physiology of certain groups of soil micro-organisms, mainly actinomycetes and fungi; and (b) relationships between micro-organisms and the roots of higher plants (rhizosphere). The staff of this section has co-operated with the A.R.C. Unit of Plant Growth Substances and Systemic Fungicides with particular reference to the breakdown of the fatty acid side chain of substituted phenoxy acids. Attention is being given to the study of the rhizosphere in relation to the utilisation and availability of phosphates.

The Forest Soils section has worked in close relationship with the Forestry Commission. The work on the development of the profile in the Culbin Forest, Morayshire, has been extended to the Lon Mor, Inverness-shire, where deep peat was afforested in 1928. Special consideration has been given to the moisture relationships and response to fertilisers in these areas. From such work it is concluded that phosphate is not a primary factor for tree growth on the dunes as it is on many upland and peat soils. Fertiliser trials have been extended to test the effect of potassium, magnesium and nitrogen upon tree growth.

The work of the Statistics section is associated at present with the department of Statistics of the University of Aberdeen. The services of this section are available to all workers within the Institute in the planning of experiments, both in the field and the laboratory, and in the analysis of the results.

The impact of fundamental studies upon fertility is the special study of the department of Soil Fertility. Investigations are directed towards the improvement of manurial practice and crop production through the better understanding of (a) the nutrient requirements of various crops, (b) the nutrient status of various soils, (c) the influence of soil properties, (d) the pedological and environmental factors, (e) the effectiveness of different types of fertilisers and liming materials, and (f) the influence of factors such as frequency of application, time of application and the method of application of such substances. The experimental approach to these problems includes the development and integration of field, pot and laboratory studies covering the main soil types and agricultural crops. The field experiments conducted by the Institute, which has a mobile field unit, are based upon the soil maps prepared by the soil surveyors and the results are submitted to statistical analysis. Close liaison with the North of Scotland College of Agriculture is maintained and reports are furnished upon the manurial requirements of soils within the College area, samples of which are submitted by the advisory officers of the College.

OUTCOME OF RESEARCH

The results of fundamental research over the past few years which may have some practical bearing on the problems of the agricultural industry may be illustrated by a few random examples.

Spectrochemical analysis of Scottish soils has led to an evaluation of the cobalt content of Scottish soils and it is possible to forecast with some degree of certainty areas where vegetation will be deficient in this particular element, the effect of which is reflected in the nutrition of sheep in particular. The routine examination of advisory samples, using spectrochemical technique, has revealed the causes of infertile areas and in particular the deleterious effect of a high content of nickel derived from an isolated serpentine geological formation. This contact with practical agriculture has provided facilities for a fundamental study of the effects of nickel upon plant growth.

The fertility of soil is somewhat determined by the rate of decomposition of organic matter and a study of the changes which lignin undergoes has been the subject of a joint attack by the microbiologists, biochemists and spectrochemists.

As was indicated earlier the Institute has always made the study of peatland its particular interest. The remit of the Moss Survey Group of The Secretary of State's Scottish Peat Committee has been widened to cover (a) the utilisation of deep peat for production of power as well as the possible utilisation of the basal mineral soil after removal of the peat, (b) the improvement of shallow peat, and (c) the utilisation of peat for afforestation and horticulture. In these studies all departments of the Institute are co-operating and special mention may be made of some preliminary results on the distribution of trace elements throughout the peat profile. Considerable assistance has been given by the staff of the Institute to the Scottish Peat Committee by the examination and evaluation of the varying types of peat and the underlying basal soils.

The joint work on the placement of fertilisers has proved of value in practice within the North College area.

The Institute publishes an Annual Report.

SOIL SURVEY OF GREAT BRITAIN

England and Wales

Rothamsted Experimental Station, Harpenden

Head of Survey: A. MUIR, B.SC., Ph.D.

Deputy Head: D. A. Osmond, M.SC., Ph.D., A.R.I.C.

B. W. Avery, B.SC.	D. W. King, B.SC., A.R.I.C.
A. Crompton, B.SC.	H. H. le Riche, B.SC.
C. A. H. Hodge, B.SC.	D. Mackney, B.SC.
R. A. Jarvis, B.SC., F.R.C.S.	R. S. Seale, M.A.

Scotland

Macaulay Institute for Soil Research, Aberdeen

Head of Survey: R. GLENTWORTH, B.S.A. (MANITOBA), Ph.D.

E. L. Birse, B.SC.	J. W. Muir, B.SC.(Agr.), A.R.I.C., N.D.A., N.D.D.
R. Grant, M.A., B.SC.	J. M. Ragg, B.SC.
D. Laing, B.SC., A.R.I.C.	J. C. C. Romans, B.SC.

Although the first systematic soil surveys in Great Britain were carried out nearly forty years ago, survey mapping methods have become standardised only during the past decade. The earliest surveys were based mainly on geology and assumed that the map of the surface geology could be translated with due interpretation into the soil map. Thus in these earlier surveys the soil was not actually mapped, and profile characteristics were practically ignored.

In England and Wales the soil survey has grown out of advisory work. From 1930 onwards soil survey work in England and Wales was co-ordinated under a Soil Survey Executive Committee, on which Scotland was represented. In 1939, the Ministry of Agriculture recognised the Soil Survey of England and Wales and appointed a Director of Soil Surveys. In 1946 it was decided that soil survey should be regarded as a research project and the Agricultural Research Council accepted responsibility for the supervision of this work. The main objective was to co-ordinate the soil survey of Great Britain and accordingly the Council set up the Soil Survey Research Board to act as an advisory body. At the same time it was decided that the Soil Survey of England and Wales should be carried on from Rothamsted Experimental Station, and that the Soil Survey of Scotland should continue to be operated from the Macaulay Institute for Soil Research.

In England and Wales there are nineteen surveyors, but it is hoped at some future date to increase this number to about thirty, which will permit about three surveyors to be assigned to each Advisory Province of the National Agricultural Advisory Service. This would also enable the staff to satisfy demands from other bodies more adequately and with less hindrance to systematic survey.

Soil maps have been made in many parts of England and Wales and a beginning has been made with their publication on the scale of 1 inch to 1 mile and the issue of explanatory memoirs to accompany them. The areas completed include Anglesey, Caernarvonshire and parts of Denbighshire and Shropshire. Surveys are in progress in Lancashire, Yorkshire, Cambridgeshire, Hertfordshire, Buckinghamshire, Somerset, Kent, Berkshire.

In Scotland there are at present twelve surveyors. The survey of Aberdeenshire and most of Roxburghshire has been completed and work is proceeding in Kincardineshire, Morayshire, Angus, Ayrshire, Stirlingshire and Perthshire. Three memoirs, with accompanying soil maps, have been published for areas in North-East, South-East and South-West Scotland. Detailed surveys of a number of forest and other areas in various parts of Scotland have also been made.

An Annual Report is issued by the Soil Survey Research Board.

A.R.C. UNIT OF SOIL PHYSICS

School of Agriculture, University of Cambridge

Director: E. C. CHILDS, sc.D., Ph.D.

The function of the Unit is to elucidate the physical problems relating to the equilibrium and movement of water in the soil. Work of this kind was initiated in the Cambridge University School of Agriculture in 1934, when Dr. E. C. Childs was appointed to the staff to study problems relevant to land drainage, including the assessment and influence of soil structure, the mechanical stability of soil in so far as it affects the permanence of structure and the longevity of mole drain channels, and the mechanics of the interaction of certain implements, such as the mole drainer, and soil. Some financial support was provided first by the Ministry of Agriculture and subsequently by the Agricultural Research Council. In 1951 the continuity of the work was assured by the establishment of the Unit of Soil Physics, in consultation and agreement with the General Board of the University and Sir Frank Engledow, Head of the University Department of Agriculture.

CURRENT WORK

While problems associated with land drainage remain a dominating influence, the solution of the fundamental physical problems which arise in that connection also have other applications, such as irrigation, soil profile development and classification, soil mechanics, and plant-water relationship. The field of practical application is now regarded as comprising soil water control and exploitation rather than drainage alone. The problem of soil water control involves estimating the necessary degree of control, and designing the means of control.

The agriculturally significant properties of soil which are modified by the soil water may depend directly upon either soil moisture content or soil water

suction. The properties themselves may be either principally biological in character (as, for example, the relative depression of crops or encouragement of weeds and undesirable organisms) or physical (as, for example, the bearing capacity for vehicles and stock, and capacity to sustain tractive effort). While the Unit is not equipped to study biological problems, it co-operates with biologists whenever possible, and has even initiated some work in this field.

Soil water content and suction are controlled by moving water into or out of the soil zone to be controlled. The controlled zone is a body of porous material in which certain known boundaries are maintained in certain known states. Thus the drains in drained land are surfaces maintained at zero hydrostatic pressure; the soil surface is a known surface at which water arrives at a known rate; in irrigated land the flooded surface or irrigation furrows are surfaces maintained at known saturation moisture content, and at great depth there is known low moisture content. All such problems resolve themselves into studies of the operation of Darcy's law of water flow in media with such known boundary conditions. It is sought in each case to discover the moisture content and water pressure (or suction) at all relevant points, preferably in the form of solutions very generally applicable to very general kinds of problem.

The nature of the soil enters into such problems by virtue of its physical property known as hydraulic conductivity or permeability. This is analogous to thermal and electrical conductivity in their appropriate contexts, and is the capacity of a standard (unit) cross section of soil to transmit water when a standard (unit) driving force is applied. The hydraulic conductivity differs from thermal and electric conductivity in not being a constant for the material, since it is influenced profoundly by the moisture content.

The complete study of water movement thus comprises study of the nature of soil permeability, and its dependence on other relevant soil properties (soil pore space geometry, structure and stability of structure, moisture content, etc.); methods of measurement of permeability in the field, bearing in mind that permeability may vary with the direction of flow; and the solution of the purely hydraulic problem of flow in given circumstances of soil and boundary conditions.

The present stage of progress may be summarized as follows:—

- (a) *Mechanical Properties of Soil.* The relevant property is the sheer strength and its relationship to normal (compressive) load. It has been established in the case of sand and kaolin clay that the strengthening effect of compressive load has its exact equivalent in the effect of soil water suction. The beneficial effect of drying land is obtained by the increase of suction. The work will be extended to more clay-like clay, e.g. montmorillonite, and the distribution of stresses in the soil due to surface loads will be examined in order to estimate what depths of soil are significant in drainage works.
- (b) *Soil Permeability.* Soil permeability is now well understood, and its value may even be calculated from pore space geometry in some favourable cases. Research methods have been devised by which permeability in the field may be completely specified. It is sought, in collaboration with the soil survey, to relate permeability to soil classification so that the findings may be widely applicable; and permeability measurements may in some circumstances be an additional tool in soil classification. Simpler methods are being sought for routine use and for use when the land has not at the time of measurement got a high water table. Surface water and groundwater problems can be objectively differentiated by permeability measurement.

- (c) *Water Movement.* The development of moisture profiles during infiltration is now quantitatively understood and some light has been thrown on subsequent redistribution. Drainage design is now well understood, and systems can be designed to control the mean water table to a desired depth given the mean precipitation. The course of water table changes following change of rate of precipitation is being studied. Confirmatory work in the field is projected.

PLANT BREEDING

PLANT BREEDING INSTITUTE

Maris Lane, Trumpington, Cambridge

Director: G. D. H. Bell, B.Sc., Ph.D.

CEREALS (WHEAT, BARLEY, OATS)

G. D. H. Bell, B.Sc., Ph.D.

F. G. H. Lupton, M.A.

R. N. H. Whitehouse, M.A.

LEGUMINOUS FORAGE CROPS AND GRASSES

J. L. Fyfe, M.Sc.

H. H. Rogers, B.Sc.

BIOCHEMISTRY

A. R. H. Trim, B.A., Ph.D.

POTATOES AND BRASSICAS

H. W. Howard, M.A., Ph.D.

SUGAR BEET

G. K. G. Campbell, B.Sc., A.I.C.T.A.

CYTOGENETICS

R. Riley, B.Sc., Ph.D.

Secretary: F. B. Hatfield, B.Sc., D.P.A.

In 1912 the Cambridge University Plant Breeding Institute was established at the School of Agriculture to develop the genetic and plant breeding work initiated by the late Sir Rowland Biffen, F.R.S. It was the first official plant breeding centre in this country, and it continued to operate under the Faculty of Agriculture of the University for 36 years, receiving a grant-in-aid from the Ministry of Agriculture, although some members of the staff were also university teachers. In 1948, the Institute was reconstituted as an independent grant-aided institute with its own Governing Body.

The present site at Trumpington, a few miles south of Cambridge, was purchased in 1950, and the work was gradually transferred from the University Farm and the School of Agriculture, the main block of buildings being occupied in 1954.

The objects of the Institute are the promotion and conduct of research and investigation, of a pure and applied nature, on plant breeding and on the factors affecting the productivity and quality of crops. The work within this context covers all kinds of crop plants, but particular attention is paid to those occupying significant positions in the farming of the intensively cultivated areas of England.

On 31st March, 1957 the scientific and experimental staff of the Institute numbered nineteen.

CURRENT WORK

In the early years of the life of the Institute a tradition of pure and fundamental research which had started with the work of one man was reflected in the expanded scope of its investigations. The work, initially confined almost

entirely to wheat, was later extended to barley and oats, so covering the three important cereals of British agriculture. The small academic staff, which never exceeded six in the first twenty years, engaged in genetic, cytological and statistical research which helped to lay the foundations of scientific plant breeding in this country. At the same time new varieties of wheat were bred which not only were classic examples of the application of scientific method to plant breeding but also contributed standard varieties which were extensively cultivated for many years in England. The demonstration that important economic characters such as disease resistance, grain quality, yield and strength of straw were heritable characters, which could be handled in segregating populations after hybridisation in a similar manner to simpler morphological characters, was a great step forward in the development of modern plant breeding methods.

The analytical approach to breeding in terms of genetics, statistics, and physiology, later to be followed by cytology, was soon recognised as the basis for crop improvement. Researches were pursued on improving selection methods in the field and in the laboratory, and although the difficulties of handling complex genetically controlled characters became increasingly apparent, attention was concentrated on the development of techniques which would include the improvement of methods for measuring genotypic expression. New characters, such as winter-hardiness in oats and barley, were used in hybridisation experiments, while sainfoin, lucerne, field beans and field peas were introduced into the programme.

Later expansion added potatoes, sugar beet, field brassicas (in particular marrow stem kale), red clover, and the rotational grasses cocksfoot, timothy, and perennial rye grass. The Institute now covers nearly all the arable crops of consequence, excepting certain crops regarded as horticultural though grown on farms. The area under field plots has increased by five times, and greenhouses are used intensively to complement the field work as well as to provide facilities for the breeding routine and for special investigations.

Pathological, cytological, chemical and biochemical departments have been incorporated, not only to help in the crop improvement work, but also to engage in fundamental research. Facilities are also available for the plant breeders themselves to deal more fully with problems such as grain quality, disease resistance and breeding techniques.

The Institute has bred seven varieties of barley, five varieties of wheat, two varieties of oats and two varieties of peas which have been marketed in this country and made their contribution to agricultural production. Some of these varieties have also been of value as the basis of further improvements by commercial breeders.

In both spring and winter wheat a great deal of attention is being given to the possibilities of combining the highest yield with the required standards of grain quality for milling, bread making and biscuit making. Improved methods of assaying quality have been introduced, and genetic studies are in progress to try and explain the major hereditary behaviour of the characters being measured. Similar work with barley has particular reference to malting quality and feeding quality, while in both barley and oats the problem of increasing winter-hardiness and combining it with other good characters is receiving attention. In the final analysis, however, the improvement of all the cereals is based on high yield, and intensive efforts are being made to increase the efficiency of breeding techniques by applying the most advanced knowledge of quantitative inheritance and of field experimentation.

The same considerations enter into the handling of all the crops, but in the cross pollinators, such as kale, sugar beet, beans, lucerne and the grasses,

special difficulties and problems present themselves in the development of better breeding techniques. In these crops the controlled exploitation of hybrid vigour becomes a prime consideration, and inbreeding behaviour, reproductive systems, sexual fertility, and sexual compatibility and incompatibility are matters for scientific study in the rational development of breeding methods. Research on these problems in field beans and kale, for example, has shown the way to establishing the basis of more scientific methods of handling these crops for their improvement.

Other methods of breeding are being studied where applicable to individual crops, or groups of crops. The Cytogenetic department has been investigating the application of artificially produced hybrid polyploids (amphidiploids) to wheat breeding and fundamental cytogenetic knowledge of considerable value has been accumulated. A large number of interspecific and intergeneric amphidiploids has been produced, and the most promising have been used for hybridising with cultivated wheat with a view to transferring valuable characters from sources which could in normal circumstances not be exploited. This technique has recently been developed on more refined lines as it involves the transfer of individual chromosomes, or parts of chromosomes, instead of whole chromosome complements. The production of polyploids without hybridisation (autopolyploidy) is being used almost exclusively in the sugar beet breeding programme, where the possibilities of exploiting triploids and tetraploids are of considerable topical interest as a means of breeding improved strains of beet for commercial cultivation.

The artificial induction of desirable mutations, as a useful technique in plant breeding, has received some attention in the cereals. Irradiation of the dry grain is the method that has so far been studied; but the experience gained at the Institute, and elsewhere, suggests that more work is needed to test more refined methods, using mutagenic chemicals. It seems probable that this will eventually impinge on the biochemical research at the Institute, which is concerned with plant nucleic acids and which has also had an interesting relevance to the study of yellows virus, the greatest scourge of the sugar beet crop.

Pathological problems demand an increasing amount of time in the breeding of crops, sometimes dominating over all other aspects of improvement. Better facilities and techniques have made it possible to breed cereals for resistance to rusts, smuts and mildews, while investigations have also started on soil borne fungi. Special programmes have also been started to deal with certain eelworms. In particular the major objective in the potato breeding work is eelworm resistance and progress has been made in building up potato varieties resistant to eelworm, and also to late blight. With other crops, such as the cereals, the long term policy is ultimately to synthesise as high a degree as possible of composite resistance to the common pathogens.

OUTCOME OF RESEARCH

Improved varieties of crop plants can make great contributions to agriculture, by way of higher yields, better quality, or greater disease resistance. Recent introductions of new barley varieties by the Institute, for example, have raised the yields of good malting barley very considerably, and these varieties contribute the bulk of the malting barley of the country. A new sugar beet variety at present being multiplied for marketing is resistant to bolting and should contribute to the efficiency of beet growing. In the improvement of such characters as winter hardiness in oats and barley, disease resistance in potatoes, field characters in marrow stem kale, and yield and quality in wheat, further advances may be expected from some of the breeding material now on trial.

WELSH PLANT BREEDING STATION

Plas Gogerddan, nr. Aberystwyth

Director: Professor E. T. JONES, M.Sc., N.D.A., N.D.D.

Assistant Director: Gwilym Evans, M.Sc.

GRASS BREEDING

Head of Department: A. R. Beddows,
M.Sc., F.L.S.

PLANT GENETICS (GRASSES)

Head of Department: J. P. Cooper,
B.Sc., Ph.D.

CLOVER BREEDING

Head of Department: W. Ellis Davies, B.Sc.

GRASSLAND AGRONOMY

Head of Department: Ll. Iorwerth Jones,
B.Sc.

W. E. J. Milton, M.Sc., N.D.A.

D. G. Miles, B.Sc.

CEREAL BREEDING

Head of Department: D. J. Griffiths,
M.Sc., Ph.D.

SEED MULTIPLICATION

Head of Department: Gwilym Evans, M.Sc.
H. M. Roberts, B.Sc.

CYTOLOGY

Head of Department: Keith Jones, B.Sc.

CHEMISTRY

Head of Department: G. ap Griffith,
B.Sc., Ph.D.

FIELD EXPERIMENTS

Head of Department: Ll. Phillips, B.Sc.

Secretary: J. O. Parry-Williams, M.B.E.

The Station was established as a research department of the University of Wales in 1919 through the generosity of Lord Milford. Sir George Stapledon was appointed Director and held this position with distinction for twenty-three years. The primary activities of the Station are the breeding and development of improved strains and varieties of grasses, clovers and oats, and the study of their agronomic behaviour.

During the last decade important developments have taken place both in the scope of the researches and in the accommodation and facilities available for research. In 1950 the University College of Wales purchased part of the Gogerddan Estate, including the Mansion and Home Farm, and, with funds supplied by the University Grants Committee, renovated and adapted the Mansion to provide for the Station a new headquarters administrative building with accommodation for a library and departments of chemistry, cytology and agronomy, together with 120 acres of land highly suitable for experimental work. At the same time supplementary laboratories and greenhouses were built for the Grass, Clover, Cereal and Seed Multiplication sections, with provision in the basement of the laboratories for the future installation of light and temperature control chambers and cold storage equipment needed for advanced research studies. A small upland nursery was also made available for the comparative study of breeding material under lowland and semi-upland conditions. The building operations and transfer to the new headquarters at Plas Gogerddan were completed by 1954.

Concurrently with these extensions of facilities for research, additions have been made to the scientific staff in the sections devoted to breeding and cytology and small research units have been established in chemistry and plant genetics to collaborate with the breeders in fundamental and other studies associated with crop improvement.

On 31st March, 1957 the scientific and experimental staff of the Station numbered thirty-seven.

CURRENT WORK

During the academic year 1955-56 more than 30 articles on the researches of the Station were published in scientific journals and the farming press. These

related to investigations into grass, legume and cereal breeding, grassland agronomy, seed multiplication, plant genetics, cytology and plant chemistry.

The severely cold weather experienced during the early months of 1956 enabled useful observations to be made on new strains and breeding material of grasses, oats and *Brassica* as regards their resistance to and behaviour under low temperature conditions, thus expediting progress in developing strains of grasses which can extend the grazing season, and of oats less susceptible to winter injury. In the grasses, new strains of a tall oat grass and a *Phalaris* hybrid, were outstanding in winter-greenness and showed considerable promise in the quest for strains which can provide herbage for grazing during February and early March. Plots of these new strains are being laid down for the study of their field behaviour under a variety of treatments so as to secure information on the best methods of management and utilization under sward conditions. Performance studies with S.170 tall fescue during the year have shown its superiority of production compared with perennial ryegrass for grazing during the spring months at a time when grass normally is in short supply.

Fundamental studies were continued on breeding techniques, and on the technique of strain assessment. Evidence was obtained of a differential response of strains to management, and of the limited, and often misleading, results which can be obtained by repeating cutting treatments to simulate grazing as compared with data obtained by the use of sheep as defoliators in conjunction with a suitable pre-grazing sampling technique. In the case of cocksfoot the cutting technique gives an under-estimate of the spring growth of herbage produced by the high tillering, more leafy, grazing strains. Other work on strain assessment techniques with a number of timothy strains has shown that the time when the first cut is made in spring relative to the primordial development in the fertile shoot has a marked influence on the rate of recovery and the contribution of herbage in the subsequent grazing period. While these observations are of fundamental importance in relation to breeding studies and strain assessment, the rate of recovery after cutting is of significance also in relation to farm practice. In these investigations of species and strain behaviour, the current work proceeding in plant genetics on the rate of leaf and tiller production in the seedling stage, its genetic and environmental control, and on the time and extent of inflorescence development, is expected to give valuable information towards elucidating the field performance of plant species. Comparisons of S.23 with Irish ryegrass in trials at the Station, and at a private upland farm, indicate the superior productivity of S.23 under upland grazing treatment, and the need for fundamental work on the relative behaviour of grass strains under hill conditions. Further work was carried out on the study of root assessment of the grasses under sward conditions, of the effects of the sward on soil structure, and of the effects on the yield of the subsequent arable crops when leys of different botanical composition and treatment are ploughed up.

Additional data were collected on legume breeding techniques in which strains are compared under single plant, drill and sward conditions, and a significant strain X treatment interaction was again obtained. Some striking differences were also recorded in cognate studies conducted under semi-upland as compared with lowland conditions. Earlier breeding experiments have shown that species of *Trifolium* are highly incompatible and that successful interspecific hybridization is rare. By employing the excised embryo technique, viable hybrids have now been obtained from *Trifolium repens* X *T. nigrescens*, *T. repens* X *T. uniflorum* and *T. hybridum* X *T. ambiguum*. Progress was also made in the development of polyploids in red and white clovers by the colchicine technique, and in the study of the progeny of induced polyploids obtained in 1953 and 1954. In the latter, four tetraploid red clover families were superior in herbage yield to the S.151 diploid control. Others were equal, or inferior. In the breeding of a large-leaved

S.100 white clover some promising plants and families were obtained in crosses between this strain and the variety Ladino. Studies and selections were also made of new material of white clover collected from Portugal, France and Germany. In red clover, breeding and selection for resistance to clover rot was continued.

Samples taken during 1956 from a long-term experiment on seed storage have given germinations of 71 per cent for red clover after cold storage for 23 years in an atmosphere of CO₂, and in the presence of a desiccant, and of 81 per cent for perennial ryegrass after careful initial drying and subsequent storage in a sealed jar for a period of 15 years at laboratory temperatures.

The cytological study of collections of cocksfoot plants from a wide range of habitats for breeding purposes has revealed the presence of chromosome races which should prove valuable for future breeding work and cytogenetic study. Experiments on the effect of embryo transplantation on the ease of intergeneric crossing in some grass species have been begun, dry embryos of *Festuca pratensis* being grafted on to *Lolium perenne* endosperm, and *vice versa*.

In the chemical assessment of herbage digestibility a new technique for fibre estimation has been evolved.

A first distribution of Foundation Seed of the new winter oat variety Powys (S.226) was made to seed growers and seed merchants during the autumn of 1956. In trials at the National Institute of Agricultural Botany two other new varieties of winter oats have given outstanding yields of grain. Progress was made in the breeding and selection of winter and spring oats resistant to mildew and stem eelworm, and in the study of the relationship between strength of straw and chemical composition. Other work pursued included the cytogenetic study of interspecific hybrids, of mutants produced by X-ray treatment and radio-active isotopes and of colchicine-induced polyploids. In field beans, inbreeding experiments were started to determine the possibility of isolating vigorous self-fertile, self-tripping lines; differences in self-incompatibility were observed. Data were collected on the field properties of a wide range of commercial kales and rapes, and advances were made in the development of suitable techniques in the handling of these plants for breeding and hybridization.

OUTCOME OF RESEARCH

The Station-bred leafy strains of ryegrass, cocksfoot, timothy and fescues, and improved red and white clovers, together with the results of the Station's researches into the establishment and management of high-quality grassland, have been major factors in the successful expansion of ley farming in England and Wales. They have provided means for the rapid improvement of lowland pastures and inferior hill grazings. The provision of a flow of Stock Seed to seed growers and the institution of seed certification schemes ensure that the new strains are made available to the farmer as authentic seed of a high and established standard of purity.

Farmers today are becoming increasingly aware of the high yields of herbage that can be obtained from well managed grass, and its low cost compared with that of imported concentrates. Needs change, and the present-day emphasis on grass, as the basis of dairy farming, cattle—and sheep-rearing, has led to an increased demand for grasses that begin growth early in spring as well as growing late into the autumn and early winter. The recently introduced S.22 Italian ryegrass and S.170 tall fescue are valuable contributions to meet this need: this too is the aim of current work on new strains of perennial ryegrass, *Phalaris* and tall oat grass.

The experiments on the effects of time of cutting on subsequent growth of the sward, and on the relative behaviour of strains under lowland and upland conditions, provide valuable information for grassland practice.

With improved soil fertility resulting from heavier applications of fertilizer to grass, the need for varieties of oats with greater strength of straw and suitable for combine harvesting is being met in the varieties S.147, S.172 and S.225, and the recently introduced variety Powys (S.226) which gained the Cereal Trophy Award of the National Institute of Agricultural Botany in 1956.

The current investigations on breeding and selecting for resistance to clover rot and on mildew and stem eelworm resistance in oats have as their aim the reduction of losses and crop failures caused by these parasitic organisms.

Finally the Station's researches into seed growing have provided more efficient seed growing techniques.

SCOTTISH PLANT BREEDING STATION

Pentlandfield, Roslin, Midlothian

Director: J. W. Gregor, D.SC., PH.D., F.R.S.E.

CEREALS

D. Cameron, B.Sc.

HERBAGE PLANTS AND GENECOLOGY

Patricia J. Watson, M.A., Ph.D.

POTATO BREEDING

W. Black, D.Sc., Ph.D., F.R.S.E.

VIRUS DISEASES OF POTATO

G. Cockerham, B.Sc., Ph.D.

ROOT CROPS AND SUGAR BEET

V. E. McM. Davey, B.Sc., Ph.D.

Secretary: R. J. L. Gallie

The Scottish Society for Research in Plant Breeding was set up in 1920. Within a year the sum of £22,363 had been raised by subscriptions and an equal sum was provided by the Board of Agriculture for Scotland. As a result, in the same year the Scottish Plant Breeding Station was established at Corstorphine, Edinburgh.

In the Station's first Annual Report published in 1922 reference is made to the receipt of a collection of breeding material from the representatives of the late Dr. J. H. Wilson of St. Andrews University comprising selections and named varieties of oats, two hundred or more strains of potato and a number of strains of swede. This collection made possible an immediate start with these three crops and thus influenced the general trend of the initial investigations. For example, Dr. Wilson's potato collection was especially valuable as a source of material for the study of blight resistance. As long ago as 1909 he had employed the Mexican species *Solanum demissum* in breeding experiments and it was observed in subsequent trials that certain of his selections remained free from blight while adjoining plots succumbed to the disease. Work on herbage plants was also contemplated at this time though it was only after a period of exploratory investigations extending over some years that a herbage programme emerged.

Up to the end of the Second World War expansion of the activities of the Station was hindered by limited staff and laboratory facilities, and it was not until 1954 when the Station moved to new land and buildings at Pentlandfield, that the situation materially changed. Complementary to the 60 acres at Pentlandfield, the Station rents land elsewhere for specific purposes and has the use of land and a potato store at Blythbank, Peebles-shire.

The aims of the Station have always been two-fold; (a) to conduct investigations calculated to yield information of scientific interest and especially information bearing upon the general problems of crop improvement; and (b) to produce new and improved varieties of direct value to agriculture.

On 31st March, 1957 the scientific and experimental staff of the Station numbered sixteen.

CURRENT WORK

The Station is organised in five Sections, each concentrating upon a particular crop or class of crops. These five Sections are—(a) Cereals, now confined to oats; (b) Herbage Plants and Genecology, a Section concerned with the breeding of arable-land grasses as well as with the constituents of the vegetation of uncultivated grazings; (c) Potatoes, a Section covering the breeding of new varieties and the study of virus diseases; (d) Brassica Crops; (e) Sugar Beet. The research programme of this last section is mainly concerned with problems of obtaining and maintaining a strain which can withstand tendencies to bolt when sown early, or under unfavourable conditions in the northern parts of the beet growing areas. This work is undertaken at the request of the Sugar Beet Research and Education Committee of Great Britain, and is co-ordinated with that of the Plant Breeding Institute, Cambridge.

During the last decade the broad pattern of the Station's work has not undergone any radical change, though certain programmes have been amplified and others modified. The study of resistance to stem eelworm has been added to the oat breeding programme, and unfixed material in the F_3 generation is now selected at three centres instead of one as hitherto, while the swede programme has been modified by transferring the emphasis from the "root" to the "leafy" brassicas.

The investigations on resistance to potato blight have changed in emphasis from "field immunity" to "field resistance". Field immunity, which implies a hypersensitive response to infection by the parasite, was first found in *Solanum demissum*. It appeared to offer a ready means of combating the disease since the character is controlled by major genes which are inherited in dominant fashion. But eventually new races of the parasite were found capable of overcoming hypersensitivity. From the evidence collected, these races are so widely distributed that the hypersensitive form of resistance must be regarded as unreliable, especially where climatic conditions favour the fungus. Consequently greater attention is now being directed towards field resistance which, as far as is known, is not affected by parasite specialisation. Breeding for resistance to potato root eelworm was started in 1952. This work has now been complicated by the discovery of eelworm populations which break down the resistance that characterised the clone C.P.C. 1673 of *Solanum tuberosum* subsp. *andigena*. At the present time the potato programme is undergoing very considerable expansion and when the new glasshouses now under construction are completed it is the intention to increase the output of seedlings from the current level of 12,000 per annum to the region of 40,000.

The discovery of field immunity to viruses X, A, B and C, led to a search for a similar response to virus Y. For this purpose the possibilities of the exotic material contained in the Commonwealth Potato Collection were explored. A gene controlling violent necrotic reaction to the virus was found in several sources, but in no case was the source material resistant to the virus. Attempts were made, therefore, to transfer this gene to a genetic environment in which its effect would lead to localisation of the virus at the site of infection. Ultimately, this was accomplished and several lines of parental material hypersensitive to virus Y have been synthesised for use in commercial breeding.

Work on herbage plants has also been expanded since the move to Pentland-field by an intensification of the genecological investigations which have all along been a feature of the herbage programme. These studies which previously had involved the examination of specially chosen species are now concerned with the structural details and potentialities of communities of species and thus indirectly with the complex problem of hill land improvement. The primary need at the moment is for more detailed information about the cause of variation within the community.

The Station's activities have in the past been almost exclusively directed towards meeting the needs of the arable farm, for such crops as oats, potatoes, swedes and sugar beet demand at least a minimum of arable cultivation. However, in a country like Scotland with such a large proportion of uncultivated hill- and moor-land the economic importance of natural vegetations is considerable, and it is not surprising that ways and means of improving them are receiving ever increasing attention. It seems reasonable to assume that in attempting to improve such grazings the emphasis should be placed on occasioning a desirable pastoral balance of sward types rather than on raising the general level of production of any one type of vegetation. Such adjustments might well involve the improvement of certain plant communities, the retention of some in their present state, and the replacement of others by alien introductions. A detailed knowledge of community constituents and their genotypic-environmental relationships would appear to be a necessary preliminary to an informed assessment of the suitability of communities for treatment as complementary entities.

The success of surface seeding experiments carried out by the North of Scotland College indicate that in certain circumstances the replacement of a natural vegetation can be accomplished without recourse to the plough and suggest that the breeding of improved strains of hill land plants for this purpose might be worth while.

The complementary value of arable and native vegetations also deserves consideration and it may be that, in this connection, while special strains of grasses are likely to be useful, other forage crops such as the 'leafy' brassicas could also be developed with the complementary principle in mind. It is, perhaps, along these lines that the Station has the best prospect of breaking new ground for, as far as the arable crops are concerned, the search for strains resistant to diseases has inevitably become the major and permanent feature of the breeding programmes.

A fuller description of the work is given in the Station's Annual Report.

A.R.C. UNIT OF BIOMETRICAL GENETICS

**Department of Genetics, University of Birmingham, Edgbaston,
Birmingham**

Honorary Director: Professor K. Mather, C.B.E., D.Sc., Ph.D., F.R.S. (Professor of Genetics, Birmingham University)

Honorary and Senior Scientific Staff:

C. J. Hickman, M.Sc., Ph.D. }
H. Rees, D.F.C., B.Sc., Ph.D. } (*Honorary Members*)
J. L. Jinks, B.Sc., Ph.D.

The Unit was formed on 1st October 1950. It is attached to the Department of Genetics in the University of Birmingham and the Professor of Genetics is the Honorary Director of the Unit.

CURRENT WORK

The purpose of the Unit is to conduct genetic investigations requiring biometrical techniques, especially investigations into the causation and control of continuous variation. In continuous variation the expression of a character (such as stature or intelligence in man, or yield in agricultural plants and animals) shows every gradation between wide limits, the central expression being

the most common and the more extreme expressions correspondingly rarer. Successful plant and animal breeding commonly depends on the confident manipulation of this variation, so that an understanding of its genetic causation and adjustment, besides being of great theoretical interest, provides a foundation for the development of improved techniques in practical breeding operations. Since continuous variation depends on the action of swarms or systems of genes, the effect of each being small but similar to the effects of the others and capable of combining with them to produce large changes, it cannot be handled and analysed by the familiar techniques of classical genetics. Rather it must be treated by the statistical techniques of biometry, and its investigation requires a combination of genetical principles with biometrical methods.

It has been necessary, therefore, to devise and define biometrical quantities which characteristically reflect the properties of genes in their transmission from parent to offspring and in the action they exert to produce their effects. These definitions have been extended to include quantities capable of representing the complex interactions of the genes not only with one another but also with the environment, so that there is now a basis for describing and analysing the relations of genes and environments in producing the local adaptations upon which the success of a variety or breed so often depends. It has also been necessary to elaborate experimental methods of measuring variation among plants and animals in such a way as to permit its analysis in terms of these basic biometrical quantities. A number of such experimental designs have been tested and compared, and one of them has shown particular promise as a means of assessing the relative breeding potentialities of a number of parental lines. This method of diallel crosses (which involves mating every one of a range of male parents with every one of a range of females), though still under experimental investigation, is now being tried for its practical value by various of the institutes concerned with breeding improved strains. Problems of inbreeding and of hybrid vigour have also been investigated. It is becoming clear that hybrid vigour may, and indeed does, arise from a variety of genetic causes, of which complex interaction among different genes in producing their effects is likely to be the most important for practical purposes.

These investigations are concerned with the understanding and manipulation of variation already available as genetic differences among contrasting types. Attempts are also in hand to measure the size and ascertain the prospective properties of new differences springing from changes induced in the systems of genes mediating continuous variation by such agencies as X-rays and the radiations associated with atomic energy. Various technical problems of experiment must, however, be overcome before these investigations can achieve full success.

The genes which determine hereditary characters are carried on the thread-like chromosomes, present in every living cell, the remarkable precision of whose behaviour determines that all the cells of an individual have essentially the same genic make-up. In their complex behaviour the chromosomes are subject to the control of genes they themselves carry, just as the members of a legislative body are subject to the laws they themselves make. Indeed chromosome behaviour is controlled by genes exactly as is any other character of the organism. It has been shown that in a normally cross-pollinating plant like rye, inbreeding upsets the regular activity of the chromosomes just as it upsets plant growth and vigour. On crossing the inbred lines hybrid vigour displays itself by a recovery of normal behaviour by the chromosomes, as well as the restoration of full vigour and fertility to the plants. The upset of the genic control over chromosome behaviour is now being investigated following wide outcrossing between species, and a picture is being built up of the way in which the chromosome mechanism—all important in hereditary transmission—has been moulded in evolution and is constantly undergoing adjustment by natural selection. Furthermore, since in

contrast to most characters of plants and animals, many observations of the chromosomes can be made in a single individual, they offer a unique means which is being used for working out the rules of genetic balance and change under varying conditions and over the whole course of an individual's development.

A difficulty which has ham-strung a number of attempts to breed plants resistant to fungal disease springs from the ability of the fungus to produce new races which are, so to speak, one jump ahead of the resistance being introduced. This has been observed, for example, in the potato blight fungus and also in its relative which causes the serious red core disease of strawberries. Tests have revealed at least 12 races of the red core fungus, though so far their mode of origin has eluded us. In the potato blight fungus a hint has been obtained that sometimes the change may depend not on the genes of the chromosomes but on adjustment of that other part of the living cell, the cytoplasm, which seems usually to play little part in heredity. Studies of other fungi, non-pathogenic but more tractable for experiment, have brought to light not only forms of gene transmission absent from higher plants, but also the important part played by the cytoplasm in determining the character of the fungus. It has become clear that the cytoplasm carries determinants having something of the permanence of chromosome genes, though without their regularity of behaviour. These determinants can change, or mutate as it is called, and they can be accumulated by selection. At present their study is only beginning, but a new field of cytoplasmic genetics is opening before us, and one which may well be of importance to our knowledge of disease causing organisms as well as widening our understanding of cell heredity and cell development.

PLANT PHYSIOLOGY

RESEARCH INSTITUTE OF PLANT PHYSIOLOGY

Imperial College of Science and Technology

Prince Consort Road, South Kensington, London, S.W.7

Director: Professor F. G. Gregory, D.Sc., A.R.C.S., D.I.C., F.R.S.

PHOTOSYNTHESIS

O. V. S. Heath, D.Sc., Ph.D., A.R.C.S., D.I.C.

NUTRITION

(Major element deficiencies)

F. J. Richards, D.Sc., F.R.S.

STOCK SCION RELATION IN THE
APPLE (Growth analysis of vigorous and
dwarfing stocks)

B. D. Bolas, D.Sc., D.I.C.

PHOTOPERIODISM

W. W. Schwabe, B.Sc., Ph.D., A.R.C.S.

SPRAY DAMAGE OF FRUIT TREES

F. W. M. Llewelyn, B.Sc., A.R.C.S.

VERNALISATION OF CEREALS

Miss O. N. Purvis, D.Sc., Ph.D.

NUTRITION (Enzymology)

Mrs. H. K. Porter, D.Sc., F.R.S.

ROOT STOCK PROPAGATION

E. S. J. Hatcher, Ph.D.

AUXIN STUDIES

C. L. Mer, Ph.D., A.R.C.S.

The aim of the Institute, since it was founded in 1919, has been to bring laboratory studies of plant physiology into closer contact with applied problems in horticulture and agriculture. This has been achieved by arrangements under which some members of the Institute staff work at Rothamsted and some at

East Malling Research Station. Others work at headquarters in South Kensington, and there is also a group at the Chelsea Physic Garden. This long standing collaboration with other research institutes has proved to be of mutual advantage. The researches in progress concern various aspects of growth and metabolism of plants, covering morphogenic problems, nutrition, carbohydrate metabolism, stomatal physiology, vegetative propagation and stock/scion relations in fruit trees, and growth substances.

On 31st March, 1957 the scientific and experimental staff of the Institute numbered fifteen.

Morphogenic problems under study include the effects of low temperature (vernalization) and day length (photoperiodism) on the flowering behaviour of winter and spring varieties of cereals. These factors, interacting in a complex way on the germinating seed and the green plant, have important practical consequences since winter cereals sown after a critical date in spring fail to produce a crop. The promoting effect of low temperature has been shown to comprise at least two stages; first a thermolabile intermediate is produced; secondly this is converted into a thermo-stable end product. The first stage can be annulled by temperatures above 15° C. (devernalization) while the second can proceed at higher temperatures. By using alternating periods of high and low temperature the dynamics of these reactions have been studied in varieties of rye. The short days to which autumn sown cereals are exposed during winter also play an important part. Thus, exposure of unvernallized winter rye to a period of short days accelerates the initiation of the ear (short day induction); similar treatment delays ear formation in spring rye or fully vernalized winter rye. A period of low temperature given to the green plant after short day induction still further accelerates subsequent flowering, which accounts for the beneficial effects of periods of low temperatures during late winter under field conditions. The work is being extended to the study of early and late varieties of wheat.

A comprehensive study has been made of the flowering responses of the Chrysanthemum, in which flower initiation eventually takes place in any day-length but under long day conditions the flower bud is inhibited and eventually aborts. Inflorescence buds produced in short days can be inhibited from further development by transfer to long days, by low light intensity in short days, or by application of auxin. Vernalization at temperatures below 12° C. hastens the formation of the flower bud in both long and short days. In contrast with the winter cereals, devernalization by high temperature does not occur; but exposure to light of low intensity destroys the vernalized condition. It has been shown that devernalization is not due primarily to carbohydrate starvation.

In *Kalanchoe blossfeldiana*, another short day plant, strong evidence has been found of the production of a flowering inhibitor in leaves in long days. In the same species it has been shown that in a sequence of short days the capacity for dark fixation of CO₂ develops concomitantly with flower initiation. If a single leaf is given short days, the dark fixation mechanism spreads to other leaves kept in long days. Once promoted, the dark fixation persists in long days for at least a year.

The central problem of morphogenesis concerns the production of lateral organs at the growing apex. Adequate methods of defining and describing the patterns of primordia at growing apices were lacking, but a method has now been elaborated in this Institute which is applicable to any phyllotaxy system. Techniques of sectioning and statistical procedures have also been developed. By these new methods an intensive study of the apical development of flax under various nutritional conditions has been made.

During and after the war, extensive work was carried out on the control of bulb development and flowering in the onion by daylength and temperature. This investigation has been taken up again, with special reference to the part played by growth hormones. A new method of bioassay has been developed using the bulbing response in onion seedlings grown in short days. Indoleacetic acid has been shown to produce a response in darkness. In the course of this work it was found that many chelating agents act as growth substances by virtue of their chelating activity, and evidence is to hand that indoleacetic acid in the plant acts in this way.

Nutrition

Previous work in the Institute has shown that various symptoms of potassium deficiency can be produced at will by varying the other cations in the nutrient solution. Chromatographic analysis of free amino acids in potassium-deficient barley leaves showed, especially in the absence of sodium, the presence of ninhydrin reacting substance identified as putrescine. Under similar circumstances, potassium-deficient flax plants accumulate arginine but no putrescine, while red clover produces a different ninhydrin reacting substance not yet identified. Putrescine fed to red clover is rapidly metabolised to the same unknown substance, and typical leaf symptoms resembling those of potassium deficiency appear. The identification of the unknown substance is under way, and the biochemical mechanism of the putrescine formation is being studied.

Potassium deficiency leads to increased respiration of barley plants. Excessive phosphate is known to be concerned, and is typical of potassium-deficient plants. By restricting supplies of both potassium and phosphate, small plants with normal respiration rates are produced, showing that the correct balance of these nutrients is the determining factor. Work is continuing on the biochemistry of respiration in potassium-deficient barley.

In view of the beneficial effects of spraying manganese-deficient plants, the transport of manganese from leaves of high content to tissues deficient in the element has been investigated, using wheat plants grown in solution culture. The minimum manganese content required for growth was two parts per million of the dry weight, but at least 10 p.p.m. were necessary to prevent deficiency symptoms. Plants transferred to a deficient solution made only limited use of manganese previously accumulated in the first two leaves or applied to the leaf surface. Leaves containing 10–15 p.p.m. lost insignificant amounts to the rest of the plant, while from leaves with 60–100 p.p.m. transport was insufficient to prevent death of the growing point or tillers.

Carbohydrate metabolism

Modern tracer techniques have made possible a renewed approach to many outstanding questions about the pathways of carbohydrate synthesis in higher plants and the regulating mechanisms. Tracer studies with ^{14}C were begun in 1950 and a photo-synthesis apparatus was constructed, in which labelled starch and sugars were prepared in sufficient quantity for use in metabolic studies. In 1952 a new laboratory was set up for enzymological studies, with assistance from the Nuffield Foundation, the Agricultural Research Council and the Central Research Fund of the University of London. Since then a quantitative study of the metabolism of sugar fed to leaf tissues has been in progress, which is co-ordinated with investigations of enzyme systems known to be associated with sucrose and polysaccharide synthesis.

From experiments employing radioactive sugars as substrates for metabolism by tobacco leaf disks, it has been concluded that synthesis of sucrose and starch includes a step in which hexose units, whether supplied free or combined as sucrose or maltose, become equilibrated and are only then available as substrates for respiration and further syntheses. Disaccharides are incorporated

without prior formation of free hexose, which appears to arise exclusively by sucrose inversion, and neither half of the molecules is preferentially used.

When $^{14}\text{CO}_2$ is supplied to tobacco leaves without depleting them of starch, it appears that a radioactive layer is formed around existing starch grains, which disappears by respiration when the leaf tissue is darkened. The redistribution of activity in the dark suggests that sucrose is on the direct pathway between starch and CO_2 ; whereas free reducing sugars are not. Evidence has been obtained of a glucose polymer other than starch which becomes labelled during assimilation of $^{14}\text{CO}_2$.

Cereal seedlings during germination synthesise sucrose and cellulose, independently of photosynthesis, from the degradation products of polymers stored in the endosperm. They are therefore useful material for investigating these syntheses from precursors such as glucose. When barley seedlings detached from the endosperm absorbed glucose labelled with ^{14}C , most of the activity appeared in the roots, less in the scutellum and little or none in the coleoptile. In the roots, the activity was found in cellulose and hemi-cellulose and remained so incorporated for at least five days, indicating that once formed cell wall substances do not turn over rapidly. In the scutellum 60 per cent of the activity present was in sucrose, suggesting that this is the major site of sucrose synthesis in the seedling.

The high rate of synthesis of sucrose in the scutellum has led to the use of this tissue as a source of enzymes for sucrose synthesis from glucose. All the enzymes necessary for this transformation have been demonstrated in extracts of wheat scutella. Sucrose can readily be synthesised by the extracts from uridine diphosphoglucose and fructose-6-phosphate, and attempts are now being made to effect a synthesis from glucose.

Leaf disks studied under controlled conditions revealed large differences in respiration rates which reflected factors operating during growth, the relative importance of which in contributing to these differences was quite unknown. In view of the importance of nitrogen in controlling growth, the behaviour of disks from plants grown under different levels of nitrogen nutrition has been investigated. The results suggest that both respiration rate and the capacity to synthesise starch are not limited by the capacity of the enzyme mechanisms specifically concerned but by the relationship between assimilation rate and growth as determined by nitrogen nutrition, daylength and other factors.

Investigation of the rate of translocation of assimilated carbon is now in progress, using tobacco and cereals, by exposing single leaves to $^{14}\text{CO}_2$ for short times and observing the subsequent distribution of ^{14}C in the plant. In the first experiments an unexpected feature was the long time during which activity remained in the exposed leaf.

Stomatal Physiology

An important new discovery disclosed the extreme sensitivity of the stomata to small changes in carbon dioxide, reduction of concentration below that normal in the air leading to opening. This occurs only over the range 0.03 to 0.01 per cent and further reduction to zero has no effect. These concentration effects operate internally and not on the outer surface of the leaf.

Even brightly illuminated leaves can deplete air only down to 0.01 per cent of CO_2 (at 25°C). This residual concentration is thus the minimum that can be reached in the internal atmosphere. Extensive study in a number of plant species has shown that the minimal concentration rises markedly with temperature, or at very low light intensity, and that it represents a balance between assimilation and respiration. The temperature effect is of interest in relation to "mid-day closure" seen in certain plants such as coffee and onion. Work is now in

progress to study the relations of stomatal movement to changes in water content, following up earlier work begun in 1935; this is a matter of great importance in the elucidation of the response of plants to conditions of drought.

Stock and scion relations in the apple

The control of "vigour" and of fruiting habit in the apple by grafting on to root stocks of various types is one of the most important cultural techniques employed in fruit growing. The growth of the composite tree may be affected by the genetic characteristics of the parts through (a) the capacity for the uptake, synthesis and utilization of nutrients; (b) the capacity for transporting nutrients through the stem tissues; (c) the nature and amounts of growth regulating substances. Work carried out in the Institute has been concerned with all these aspects.

Representative vigorous, intermediate, and dwarfing rootstocks have been grown as ungrafted cuttings in water culture at different levels of nutrient supply, and by the method of growth analysis the net assimilation rate has been determined. Large differences were found between the root-stocks, the vigorous stocks always displaying the higher assimilation rate. The differences were shown to be due to the effect of the root and/or stem by grafting a single scion on to the various rootstocks; for under these conditions the assimilation rates of the leaves of the uniform scion differed as much as those of the leaves produced by the ungrafted stocks. It was further shown that in the early stages of growth the differences in net assimilation rate were not apparent, but these developed in the course of the seasonal growth. It is concluded that these differences may be due to differential rates of senescence of the leaves, produced by the root-stocks in the ungrafted plants, or induced by the rootstocks in the leaves of the uniform scion grafted on to the various rootstocks. Grafts have been studied with the three types (vigorous, dwarfing and intermediate) combined together in all possible ways as stock and scion. No differences in assimilation rate have been found in the early stages of growth, though differences in vigour due to the effect of the stocks appeared as expected. Work is now proceeding to estimate directly the assimilation rate of the attached leaves and thus to confirm or refute the results of growth analysis.

Growth Substances

Work has been going on for some years on the estimation of growth substances in apple and plum stool bed shoots during active growth and in the dormant period, with particular attention to the effects of temperature and oxygen supply on the transport of native auxin in woody stems. Other studies have included the chromatographic analysis of growth promoters and inhibitors present in extracts of stem tissues; the relations of the auxins present to extension growth; the properties of the isolated inhibitors; and the interaction of inhibitors with natural auxin in the standard coleoptile tests. Following on previous work concerned with the rooting responses of hardwood cuttings of apple to various growth promoting substances, the effect of conditions of storage previous to rooting on such responses is now being investigated.

A.R.C. UNIT OF PLANT CELL PHYSIOLOGY

Department of Agriculture, University of Oxford

Director: R. Brown, D.Sc., Ph.D., F.R.S.

Senior Scientific Officer: N. Sunderland, B.Sc., Ph.D.

The Unit was started in the Department of Agriculture at Oxford in 1953, with the present Director as the sole member of its staff. The work of the Unit has been concerned mainly with the cellular phenomena involved in growth and differentiation. This has involved investigations of the physiology of cell expansion and cell division and a detailed examination of the physiological characteristics of meristems, which are the regions in which these processes are most active.

CURRENT WORK

The process of cell expansion, it has been shown, is not a simple process of inflation, but one in which the various components of the cell increase in mass, and in which the metabolic characteristics of the whole system change with time. In the cytoplasm not only does the quantity of protein increase but also the relative activities of different enzymes change. The change in protein and in the metabolic pattern determined by changes in the enzyme complex are most important aspects of the situation, and during the last two years these have been explored further through a detailed study of the nucleic acid composition of the cell during development and through an examination of the effects of certain purine and pyrimidine analogues on the formation of particular enzymes. It has been found that, with expansion, certain characteristics of both the ribose and the desoxyribose nucleic acids change. Also it has been found that, when 8-azaguanine is fed to root tissue, this substance becomes incorporated into RNA and, as a result, induces considerable changes in the enzyme pattern, which ultimately affect growth and development.

The study of cell division has been developed with root meristems. A technique has been elaborated for measuring the relative durations of each of the phases of the division cycle, and the effects of a variety of conditions on the overall cycle have been analysed. It has been found that the whole process in the root is profoundly affected by conditions that might be expected to influence aerobic respiration. It is very rapidly depressed by anaerobic conditions and by cyanide. It is significant, however, that the depression affects only the interphase and early prophase. As soon as metaphase has been reached the depression in respiration apparently has little or no effect. In this connection the results of an investigation by a visitor to the Unit, on the effects of iron on growth, are of some interest. It was found that the cessation in growth when iron is withheld is due entirely to an arrest in division, which is apparently related to a high iron requirement in the nucleus. This observation is likely to be of some economic importance in relation to nutrition.

The studies on the intact meristematic regions, in which division and expansion proceed, have during the last two years been restricted to the apex of the shoot. Appropriate techniques have been elaborated and, with these, a detailed examination has been made of the volume, number of cells, protein content and respiration in each morphological zone of an apical fragment which carries a dome and the first seven primordia. This investigation has shown some unexpected features in the development of the shoot, which are likely to be of considerable importance for the interpretation of the growth of the plant as a whole.

The techniques developed in the study of the apex were used by a visitor to the Unit to study the effect of water stress on the apical region. It was shown

that while in the mature regions of the plant the withdrawal of water may lead to considerable disorganisation, similar effects are not observed in the embryonic apical regions. In the apex with the development of stress, water is withdrawn and the volume shrinks. But this effect is not accompanied by disorganisation even after prolonged drought. A further analysis of this situation might yield results of great economic importance for the control of plant growth in conditions of drought.

PASTURE

GRASSLAND RESEARCH INSTITUTE

Hurley, near Maidenhead, Berkshire

Director: William Davies, D.Sc.

LEY AGRONOMY

Head of Department: T. E. Williams, B.Sc.

A. J. Heard, B.Sc., M.Sc.

W. Stiles, M.Sc.

ANIMAL AGRONOMY

Head of Department: F. E. Alder,

D.F.C., B.Sc., M.A.

C. R. W. Spedding, M.Sc.

J. C. Tayler, M.A., Dip.Agric.

HERBAGE AGRONOMY

Head of Department: J. O. Green, M.Sc.

H. K. Baker, B.Sc., Ph.D., Dip.Agric.

D. W. Cowling, B.Sc.

BIOCHEMISTRY AND ANIMAL NUTRITION

Head of Department: W. F. Raymond,

B.A., A.R.I.C.

J. M. A. Tilley, B.Sc., D.Phil.

PLANT PHYSIOLOGY

Head of Department: F. H. M. Langer,

B.Sc., Ph.D.

R. D. Williams, B.Sc., Ph.D.

MICROBIOLOGY

Officer in Charge: Miss E. Grossbard,

Ph.D., D.I.C.

STATISTICS

Officer in Charge: C. D. Kemp,

B.Sc., Dip. stat.

Secretary: R. P. Brailli, F.S.C.

Librarian: W. J. Baulkwill, B.A., N.D.A.

The Institute was established in 1949. Its forerunner, the Grassland Improvement Station at Drayton, Stratford-on-Avon, was under the direction of Sir George Stapledon and dealt with the improvement of derelict lands. After the establishment of the new Institute, the emphasis of the work changed and a long-term research programme was initiated.

The land occupied by the Institute at Hurley extends to some 630 acres including 89 acres at Hodgedale. When this was acquired, the only building was an old radar hut which became a temporary laboratory. Building began in 1950, when a start was made with farm buildings and workers' cottages, and ended in 1955, when the transfer of the scientific staff from Drayton to Hurley was complete and the new research laboratories were in full occupation.

The Hurley lands are now in a ley system of farming, usually the length of the ley being determined by the needs of research. Similarly the pattern of cropping, though following a broad schedule of four years grass and two years arable, is flexible and subordinated to the demands of the experiments. Over 200 Hereford cross cattle are employed in experiments. The sheep flock amounts to about 600 head. They are used in experimental plots, either as defoliators or as subjects for investigation in those experiments where the grazing animal is used to evaluate pasture. There is also a pig and poultry unit used to determine

the influence of the non-ruminant on pasture and *vice versa*. Both pigs and poultry have been used at the Institute for the evaluation of "leaf protein" extracted from grass and clover leaves.

On 31st March, 1957 the scientific and experimental staff of the Institute numbered forty-nine.

CURRENT WORK

Herbage Agronomy. The work includes tests on strains, seeds mixtures, management of grassland, seed production, grassland ecology and the autecology of pasture plants including such aspects as the influence of herbicidal treatment upon botanical composition and yield. A considerable part of the experimental work is concentrated on the extension of the grazing season, including the use of various techniques for providing out of season pasturage. In this respect the use of cocksfoot grown in widely spaced drills (14-24 inches apart) has been confirmed as a reliable method of providing winter grass.

The problems of full utilisation are under intensive study. Much of the initial field work in seed production of the grasses is completed but new problems are now under investigation, particularly the influence of spacing upon seed yield. The place of white clover and other legumes as sward components is being investigated under a variety of manurial and management treatments. The legume component is an important instrument in sward productivity and has a prominent place in the research programme.

Animal Agronomy. It has been shown that calves can be successfully reared at pasture with milk substitute as a supplement for the first 12 weeks. In one experiment no concentrates were used, yet the calves showed live weight gains only slightly inferior to multiple suckled calves. Studies of the calf at grass have emphasised the importance of maintaining health, "husk" and stomach worms being particularly important.

Experiments with yearling cattle include a comparison of differently constituted leys measured in terms of live weight increment. An attempt is being made to correlate intake of pasture with daily gain in weight, by the use of chromic oxide as an indigestible marker. In the case of fattening cattle, new techniques of management and use of fertilisers are being studied for the purpose of extending the fattening period into early winter. Carcass weights and quality are recorded throughout.

The work with sheep is concerned with the ewe and lamb. The behaviour, including weight gains, of worm-infected and worm-free sheep, has been recorded over several seasons. Worm-free ewes have produced lambs which at birth were about one third heavier than those born of infected ewes. Ewes overwintered on foggage (special purpose leys), produced lambs as heavy at birth as those ewes fed on grass and concentrates. Lambs from ewes that were well fed during late pregnancy and early lactation gained weight more rapidly than when the ewes were less well fed. Lamb growth made on "short" compared with "long" pasture seems to be similar. This study, started in 1956, will be extended, for the position can be complicated by the differential worm burden of sheep under different systems of pasture management.

Ley Agronomy. The influence of the ley on soil conditions forms part of a long-term programme. The grasses appear to have little differential effect upon crop yield but the influence of the legume, as a ley component, is most marked. Output from grassland is raised by the use of nitrogen although its continued use may depress the legumes. Where the ley is grazed and receives dressings of nitrogen fertiliser the yield of the subsequent arable crop is raised but not so when the ley is cut and the grass removed.

The ley influences certain soil properties; thus the content of organic matter and of nitrogen is increased when land is in grass. There appears to be a good correlation between mineralisable nitrogen in the grassland soil and the yield of crop which follows ploughing up. The physical structure of the soil improves under grass and this is related to age of ley. Only small differences are found between the various species of grass in respect of effect on soil structure. Investigations have been continued into the effect of irrigation on the growth of grasses and clovers, in order to build up a body of data which will indicate the most efficient use of water for different species of grassland plants.

Biochemistry and Animal Nutrition. In the nutrition studies, the emphasis has been on improvement of the faecal index techniques which are now being extended into the field to estimate pasture intake. There are good reasons for suggesting that the main deficiency on pastures is in the intake of energy rather than of crude protein. A detailed study is therefore being made of the polysaccharides in herbage, since much of the energy is derived from their digestion by the ruminant. Previous work by the Institute emphasised the lack of knowledge of the nitrogen fraction in grass, and detailed studies are therefore being made of the protein in herbage. These studies may prove of practical value in connection with the feeding value of various herbages.

Plant Physiology. A major line of work deals with the history of the grass tiller under a variety of conditions. Work with timothy and meadow fescue suggests an almost continuous change in tiller population of the sward just as was previously found with single plants. Work continues on photoperiodism of S.48 timothy, a long day plant requiring some 5-6 weeks of long day conditions to promote normal flowering. Studies in seed production suggest that the major part of the seed crop, in meadow fescue, is produced by tillers already present by March of the crop year. This work leads to an endeavour to promote early tillering and so increase the volume of seed. Associated with this investigation is work on nitrogen nutrition of the grass plant since it is established that nitrogen increases seed yields. High levels of nitrogen tend to increase tillering and ear production as well as size of leaf and of inflorescence.

Dissection of apices in a number of grasses has been made to determine the time of differentiation and position of flower embryo in the shoot. This information will be used in connection with field studies in grazing management where flower production is to be prevented. In root studies, lithium is being used as an inactive tracer which may make it possible to map the lateral distribution of roots in the field. Radio-isotopes are also being used to investigate nutrient uptake and to follow the distribution of nutrients after absorption by the plant.

Statistics. This unit, though small, is of value to the Institute as a whole in the planning of experiments and in computation. Subjects under study include an examination of point quadrat data, improved designs and interpretation of animal experiments; analysis of serial harvests off the same pasture plots; leaf area estimation; and problems associated with estimates of fodder digestibility.

Microbiology. This newly established unit studies decomposition of plant material, particularly roots, and ill thrift in lucerne. Unthriftness is aggravated by competition from weeds and mitigated by liming. The symptoms appear to be those to be expected from lack of nitrogen and are possibly due to ineffective rhizobial development linked with inadequate nutrition.

Extra-mural work. The Institute carries out trials, in co-operation with the advisory services, which are essentially an extension of its own investigations and provide additional data within the research programme. These trials have already been established at about a score of different centres throughout the country and deal with winter grass production, differential manuring of leys,

weed control by herbicides and a study of certain problem areas on the eocene soil in the southern counties, e.g. Bagshot sands.

OUTCOME OF RESEARCH

While much of the work is long term, it has obvious practical implications, particularly in relation to extending the grazing season and the better use of grass. It is accepted that grass provides the cheapest feed for the ruminant animal and has also a not unimportant place in the rearing of pigs and poultry. Any extension of the grazing season, whether in spring and autumn or during summer drought, is of economic value. The Institute's work with lucerne and other leys has shown how to reduce the summer gap in pasture production, while store cattle as well as sheep have been carried in thrifty condition right through winter on pasture supplemented by silage or hay for only some 6-7 weeks in February and March. This work has had an important impact upon grassland thought not only in this country but elsewhere. Many problems in the production and use of winter pastures still await solution. Pasture of higher nutritive value is needed and more of it, and the problem of keeping animals out of doors on winter pasture still raises a number of questions which are not resolved. It is, however, clear that given adequate food the ruminant animal can thrive out of doors even during inclement weather.

The researches on internal parasites in sheep and young cattle have focussed attention on the serious reduction in thrift that they cause, even when the worm burden is at sub-clinical level, and has shown that many of the worst ills can be controlled by better pasture management.

The work on animals also suggests that good pasture provides valuable feed for very young calves which from three months of age can be raised on pasture only and still make normal live weight gains.

The use of the ley as a soil fertility improver is well recognised but work in the Institute has emphasised the value of high production while under grass and the importance of the *grazed* sward carrying an adequate legume component. The demonstration of the importance of full return of dung and urine to the sward has an obvious practical bearing.

One of the most striking practical effects of the work of the Institute has been the complete acceptance of grass as a crop which demands to be farmed well and to be maintained at high fertility levels. In pre-war days the farmer did little to improve his grassland; today it receives major attention on most lowland farms. It may, indeed, be that production has outstripped utilisation since grass is notoriously difficult to manage on the farm because of its uneven growth at different seasons and because as a crop it is in a continual state of flux with an ever-changing tiller population and with associated changes in nutritive value.

The annual report of the Institute is published as *Experiments in Progress* and gives in some detail the range of projects that are under study.

HORTICULTURE, GLASSHOUSE CROPS AND FRUIT

JOHN INNES HORTICULTURAL INSTITUTION

Bayfordbury, Hertford, Herts.

Director: K. S. DODDS, D.SC., Ph.D.

GENETICS

Head of Department: D. Lewis, D.SC., Ph.D.,
F.R.S.

A. J. Bateman, B.SC., Ph.D.

PLANT BREEDING

Head of Department: Watkin Williams, M.SC.

G. J. Dowrick, B.SC., Ph.D.

G. M. L. Haskell, B.SC., Ph.D.

CELL BIOLOGY

Head of Department: L. F. La Cour, M.B.E.

J. Chayen, Ph.D.

J. McLeish, B.SC., Ph.D.

POTATO GENETICS

Head of Department: K. S. Dodds,
D.SC., Ph.D.

J. B. Harbone, B.SC., Ph.D.

PHYSIOLOGY AND PLANT CULTURE

Head of Department: W. J. C. Lawrence,
O.B.E., V.M.H.

R. M. Whittle, B.SC.

Secretary: G. R. Davies

The John Innes Horticultural Institution was founded in 1910 at Merton, ten miles south of London. Any marked expansion there was impossible owing to suburban development and in 1945 an estate of 372 acres was acquired at Bayfordbury to which the Institution moved in 1949.

On 31st March, 1957 the scientific and experimental staff of the Institution numbered thirty-nine.

CURRENT WORK

Genetics. The Genetics department is concerned with differences arising from gene mutation. It is not surprising, therefore, that the department is especially interested in how genes change in nature and by special treatments inducing changes. One gene, that at the incompatibility locus in flowering plants, has been selected for intensive study. Mutations have been induced by X-radiation and their subsequent behaviour in breeding experiments has been analysed. The technique of inducing mutations to self-fertility has been applied to sweet cherries, apples and pears. The department is also making a general survey of the breeding systems in flowering plants, work which has a bearing on the practical breeding of crops.

Recently the department has turned its attention to the mushroom *Coprinus lagopus* which has several features in its life history that make it a useful organism for studying the interaction of nucleus and cytoplasm in heredity. As a preliminary to this work, biochemical and morphological mutants are being obtained to be used as markers in the genetic experiments.

Cytology. This department is particularly interested in changes that occur in chromosomes. How chromosomes are broken and what happens to them afterwards have a direct bearing on plant breeding and on the health of the cell. It has been found that chromosomes of *Trillium* undergo spontaneous breakage in *Paris* cytoplasm. The chromosomes of species of *Trillium* are being used in such hybrid endosperms to see if their different behaviours are related to the amounts of heterochromatin in them. Several cytochemical investigations are also being carried out. An attempt is being made to identify and assess the

significance of a lipoidal material that appears to coat the chromosomes during mitosis and is also associated with the protein in the framework of the chromosomes. The amounts of desoxyribose nucleic acid (DNA) in different regions of the root and its localisation in the cell are being examined. A similar study is being made of amino-acids in the cell.

The department also concerns itself with more general cytological surveys of certain genera to try and find out how some of our cultivated plants have arisen by the selection of forms with special sets and kinds of chromosome.

Pomology. In this department endeavours are being made to obtain new varieties of fruits and vegetables by hybridisation and selection. An extensive programme of apple breeding is being undertaken to try to raise varieties resistant to Scab (*Venturia inaequalis*). Both cultivated varieties and wild species of *Malus* are being used as sources of resistance. Strawberry breeding is an urgent activity in the department, owing to the acute shortage of good commercial varieties in the trade, and several very promising varieties are at an advanced stage of selection.

In tree crops, use is being made of mutagenic agents, notably radio-active phosphorus, to try to produce new and useful variants, which can subsequently be increased by vegetative propagation. The department also devotes some of its resources to improving tomatoes. Two F₁ hybrids have been successfully introduced into commerce and, in collaboration with the Genetics department, attempts are now being made to make the female parent in the combination male-sterile, so that the production of uncontaminated hybrid seed will be simplified. Genes with easily recognisable effects are also being bred into the parents to simplify certification of the hybrid seed. An attempt is being made to introduce a character called suppressed lateral into a commercial variety. This mutation occurred spontaneously and its interest lies in the economy that would follow the elimination of the need to remove side shoots. Unfortunately the mutation has several undesirable effects and they must be overcome before its potential value can be realised. A study is also being made of the evolution of species in the genus *Rubus*.

The department maintains the National Rose Species Collection and general collections of species likely to be useful in the fruit breeding programme are being assembled and identified.

Potato Genetics. The research programme of the department embraces studies of the cytology and genetics of tuberous *Solanums*, of their resistance to diseases and pests and of their use in the synthesis of tetraploid breeding lines for crossing with domestic potatoes. Particular attention is being given to the development of varieties with resistance to some of the commoner viruses, for example, X, Y, and leaf roll. Some of the Mexican species are valuable sources of genes for resistance to late blight and are being used in the breeding programme.

The species of the collection show a most interesting variability in the occurrence of various polyphenols. They are being used to study the inheritance and biosynthesis of these common substances of plants.

Physiology and Plant Culture. This department uses the glasshouses at Bayfordbury to investigate the efficiency of natural illumination as determined by size of glass, orientation and roof shape. Other components of glasshouse climate such as temperature, ventilation and water and nutrient supply are also being studied. Further work has dealt with the effect on seedling growth of different kinds of artificial light as a supplement to natural light in winter time. A special object of the work on glasshouse climate and plant culture has been to obtain the highest practicable control of the plant in order to increase the precision of experimentation. The effects of light and temperature on the

development of the tomato are also being studied by the use of controlled environment rooms.

OUTCOME OF RESEARCH

From its inception, the Institution has carried out a programme of work in which fundamental and applied research are equally balanced. Methods evolved at the Institution to grow plants for experiment have been widely adopted in private and commercial horticulture. The use of potting and seed composts prepared according to formulae devised by the John Innes Horticultural Institution is now standard gardening practice. The use of mercury vapour lamps to supplement natural light for early glasshouse grown tomatoes is also a method devised at the Institution and adopted by many progressive growers in the tomato industry. These and other practical recommendations are published as John Innes leaflets. Fourteen have now been issued dealing with a variety of topics including soil ingredients of the composts, raising plants in soil blocks and the balanced steaming of glasshouse soils.

A variety of organisms have been used to try to discover the laws governing heredity and evolution in plants and animals generally. These findings have been applied to breeding new fruits and flowers. The discovery of incompatibility in cherries and other work on the flowering of apples and pears led to the definition of fertility rules for planting fruit trees. The knowledge of which varieties should be grown together to ensure efficient pollination has had a profound effect on the planting of orchards. Several varieties of crop plants bred at the Institution seem likely to become established in commercial horticulture. The cherry varieties Merton Heart, Merton Bigarreau and Merton Glory, and the apple Merton Worcester are highly regarded by commercial growers. The strawberry Merton Princess has been received favourably and is now being bulked up through the Nuclear Stock Association prior to general distribution. One or two pear selections are also ready for release.

The Institution has pioneered certain breeding work with the tomato. It bred the varieties Antimold A and B, the first to be produced in this country with resistance to leaf mould (*Cladosporium fulvum*). Later, attention was given to hybrid varieties and Hertford Cross and Ware Cross were produced. The latter has been well received by the industry and is being grown extensively.

A progress report is published each year.

GLASSHOUSE CROPS RESEARCH INSTITUTE

Rustington, Littlehampton, Sussex

Director: F. W. Toovey, O.B.E., B.Sc., A.R.C.S., A.I.C.T.A.

CHEMISTRY

Head of Department: G. W. Winsor, Ph.D.

J. N. Davies, B.Sc., Ph.D.

J. H. Messing, B.Sc.

ENTOMOLOGY

Head of Department: N. W. Hussey, Ph.D.

MYCOLOGY AND VIROLOGY

Head of Department: P. H. Williams, B.Sc.

P. B. Flegg, B.Sc., A.R.I.C.

PLANT PHYSIOLOGY

Head of Department: E. R. Leonard,
D.Sc., A.R.C.S.

A. J. Cooper, B.Sc., Ph.D.

L. A. Darby, B.Sc.

H. R. B. Hack, B.A.

INSECTICIDES AND FUNGICIDES

Head of Department: W. H. Read,
M.Sc., A.R.I.C.

Nursery Manager: J. M. Evans

Secretary: J. Bishop, A.C.I.S.

Librarian: Miss G. Dunster, B.A.

The Institute was established in 1953 with the task of "promoting scientific research bearing on the cultivation of glasshouse crops and mushrooms, and of bulbs, flowers and shrubs grown in the open, and on matters ancillary thereto". The Institute took over the functions of the Experimental and Research Station

at Cheshunt which was in existence from 1915 until it was finally closed down early in 1955. By arrangement with the Mushroom Research Association Ltd., the work of the Mushroom Research Station at Yaxley has similarly been absorbed.

The Institute is in the heart of the important West Sussex glasshouse area. It occupies about 100 acres of land, the soil being mostly of the brick earth type which is considered very suitable for cultivation under glass. Development of the site was begun in 1953, and the first glasshouses were ready for cropping in 1954. These houses were of the ordinary commercial type and were intended for relatively large scale trials and experiments. Other glasshouses specially designed to meet the more exacting needs of the research departments were subsequently planned and are in course of construction. The first laboratory block was completed early in 1955, and this permitted the transfer of the administrative and research staff from Cheshunt, some members of the Yaxley staff also joining the Institute at about the same time.

On 31st March, 1957 the scientific and experimental staff of the Institute numbered twenty-six.

CURRENT WORK

The current programme of research is confined to glasshouse crops and mushrooms, and it will be some time before any work on outdoor flowers and bulbs can be initiated. Of the glasshouse crops the tomato is by far the most important, but variety trials on cucumber and lettuce have been started, and some attention is being given to those important flower crops grown under glass, the carnation and the chrysanthemum.

Plant Physiology. This department is carrying out a fundamental study of the growth characteristics of the tomato. Factors of the glasshouse environment likely to influence growth, in particular soil moisture tension, are also being studied. The growth analysis has shown that there is a well marked seasonal trend in the development of most of the above-ground organs of the plant and this is related to the similar trend found in the development of the roots.

Chemistry. The department has continued to study the mineral nutrition of glasshouse crops which was under investigation at Cheshunt for many years. From the purely descriptive studies of deficiencies in the earlier years attention has been directed to plant growth at various concentrations of the element in question, and the boron requirements of the tomato have been studied in this way. From the earlier work striking effects resulting from boron deficiency were noted in various other glasshouse crops, and these observations are useful for diagnostic purposes.

The department has also attempted the development of a slow-acting nitrogenous fertilizer of the urea-formaldehyde type. The chemistry of urea-formaldehyde reaction products is complex, but promising compounds of this type have been synthesized in the laboratory and are being prepared on a larger scale for plant growth trials in the glasshouses.

In another field the work of the Department has taken a biochemical turn. The organic constituents of the tomato fruit are being studied with a view to elucidating the variations that occur in fruit quality, and chromatographic methods have demonstrated significant differences in the concentration of sugars, organic acids and total solids in the sap of normal and "blotchy" fruit. This work, in conjunction with preliminary studies by the Plant Physiology Department on the incidence of "blotchy ripening" under ordinary glasshouse conditions, is throwing valuable light on a problem that is of considerable concern to every glasshouse grower.

There is also in hand an extensive programme of analyses, both of soils and tomato foliage, in connection with the "calibration" of two blocks of glass-houses to provide information on the variations that occur in these blocks.

Investigation of some of the cultural problems of mushroom growing is also included in the department's programme. The function of the casing layer and the mechanism of sporophore initiation are regarded as matters of primary importance, and a study of some nutritional aspects of fruiting is already in progress. The effects of organic carbon sources, inorganic nutrients and the concentration of soluble salts in the casing layer are being examined in preliminary pot experiments.

Plant Pathology. Among the diseases being studied by this department are Stem Rot of tomato caused by the fungus *Didymella lycopersici*, mildew on cucumber, and the various wilt diseases of the carnation. Stem Rot can be a most devastating disease wherever tomatoes are grown as the whole plant may be killed within a short time. Control measures are usually based on the strictest possible hygiene, but there are many aspects of the matter which require investigation. There is much evidence that spread of the disease is more rapid in sterilized than unsterilized soil, and the reason for this is being sought in the laboratory. It seems probable that the failure of *D. lycopersici* to establish itself in unsterilized soil is due to the presence of other micro-organisms, and work is in progress to determine which group of soil organisms is chiefly concerned and the mechanism of the suppressive action. The work on cucumber mildew and the carnation wilt diseases, which are very widespread in glasshouse practice, is at present largely confined to isolating and identifying the principal fungi and races of fungi concerned. For the cucumber disease this has necessitated evolving a technique for maintaining cultures of the fungus on living plants growing under sterile conditions in large test tubes, as the fungus is an obligate parasite and cannot be maintained in artificial culture in the normal way.

Disorders of the mushroom characterised by reduced cropping and, sometimes, the production of abnormally shaped fruit bodies, which are now causing so much concern to growers, are also being studied. These disorders go by a variety of names, among them "La France" disease. Several cultures of mushroom mycelium from commercial crops thought to be affected by this disease have been used for experiments in pots, but the work is still in its early stages.

Some attention is being given to virus diseases, particularly tomato mosaic and the numerous diseases which affect the carnation and chrysanthemum, but the staff and facilities available for this work are at present limited.

The principal entomological problems under investigation are the Greenhouse Red Spider Mite and the pests of the mushroom. A useful advance has been made in the study of the former pest by the elucidation of the different colour forms in which it can exist. This has an immediate practical bearing on control measures and shows the importance of using pure strains of the mite for testing acaricides.

Crop Protection. An examination is being made of new substances for use as insecticides and fungicides. The value of 2 : 4 dinitro-6-secocetylphenyl crotonate for the control of cucumber mildew has been established, but other substances which might be cheaper and offer less risk of damage to the crop when used at high concentrations are being studied. Several members of a series of compounds synthesized in the laboratory have shown promise, and further work on these and related compounds is proceeding. Alternatives to ethyl mercury phosphate for the control of *Didymella* Stem Rot of tomatoes are also being sought, and the experiments include trials with antibiotics.

This department is also continuing its efforts to find better means of controlling the Greenhouse Red Spider Mite, with special emphasis on the control

of the mite on cucumbers, since these plants are susceptible to damage from nearly all the persistent acaricides normally used. In conjunction with this work fundamental studies on the penetration into leaves of some of the newer acaricides have been carried out, and the problems of persistence and hazards to workers and consumers are being investigated.

Plant Breeding. The appointment of a Plant Breeder has made it possible to intensify work on the improvement of crop varieties, in particular of the tomato and cucumber. With the tomato, the general aim is to produce a variety with all the good characters of "Potentate", the variety most widely grown under glass, but with none of its imperfections. Special attention is being given to early and total yield, fruit quality and disease resistance, and it is also hoped to introduce the short-jointed character of the "Baby Lea" variety. Varieties are being tested under forcing conditions on steamed soil, in an attempt to meet the special needs of those growers who aim at producing the early crop, and also with later planting on chemically sterilized soil. As a subsidiary study a large number of varieties have been examined for their ability to produce pollen and set fruit under winter light conditions. With the cucumber, early and total yields are again receiving particular attention, but fruit characters, and possible resistance to leaf mildew, are also kept in view. The production of sterile triploid plants which will not produce any pollen and so cannot set seeded fruit even when bees enter the glasshouse is also being investigated. A preliminary investigation of lettuce varieties suitable for winter forcing under glass has also been made.

The Institute publishes an Annual Report.

EAST MALLING RESEARCH STATION

East Malling, near Maidstone, Kent

Director: F. R. Tubbs, M.Sc., Ph.D., A.R.C.S., D.I.C., F.L.S.

Assistant to Director: T. N. Hoblyn, O.B.E., Hort. Dip.

POMOLOGY

Head of Department: W. S. Rogers,
M.A., D.Sc., Dip.Hort., A.Inst.P.

Miss A. B. Beakbane, Ph.D., N.D.H.

R. J. Garner, M.Sc., N.D.H., Dip.Hort.

R. L. Knight, O.B.E., D.Sc., A.I.C.T.A.,
Dip.Agric.

Miss I. Modlibowska, Ph.D.

Miss B. G. Mosse, B.Sc., Dip.Hort.

STATISTICS

Head of Department: T. N. Hoblyn,
O.B.E., Hort.Dip.

Deputy Head of Section: S. C. Pearce, Ph.D.

G. M. Jolly, B.Sc.

PLANT PHYSIOLOGY

Head of Department: H. W. B. Barlow, B.Sc.
D. H. Maggs, B.Sc.

BIOCHEMISTRY

Head of Department: A. E. Flood,
M.A., Ph.D.

PLANT ANALYSIS

Head of Department: A. C. Mason,
B.Sc., F.R.I.C.

FRUIT NUTRITION

Head of Department: D. W. P. Greenham,
M.A., Ph.D.

Secretary: T. R. Littlehales

Miss A. V. Delap, B.A., B.Sc.
J. E. Goode, B.Sc.

PLANT PATHOLOGY

Head of Department: R. V. Harris,
D.Sc., A.R.C.S., D.I.C. M.I.Biol.

M. H. Moore, M.Sc., Ph.D., Dip.Hort.

A. F. Posnette, M.A., Ph.D., A.I.C.T.A.

J. E. Crosse, B.Sc., Ph.D.

D. S. Kirkham, Ph.D.

P. W. Talboys, Ph.D., D.I.C., M.I.Biol.

ENTOMOLOGY

Head of Department: A. M. Massee,
O.B.E., D.Sc., F.R.E.S.

G. H. L. Dicker, Ph.D., A.R.C.S., F.R.E.S.

R. S. Pitcher, Ph.D., Dip.Agric., Dip.Entom.

Miss E. Collyer, Ph.D.

L. A. Lickerish, M.A., B.Sc.

PLANT PROTECTIVE CHEMISTRY

Head of Department: A. H. M. Kirby,
M.Sc., Ph.D., A.R.I.C.

M. Allen, B.Sc.

R. P. Tew, A.R.I.C.

SCIENTIFIC LIAISON

Head of Department: H. B. S. Montgomery,
B.A., Ph.D., D.I.C.

F. W. Andrews, D.Sc., Ph.D., A.R.C.S.

Librarian: S. R. Ball, B.A. F.L.A.

The Station was founded in 1913 as a fruit experiment station of Wye College. It became an independent research institute in 1920 under the governance of the Kent Incorporated Society for Promoting Experiments in Horticulture.

Today, the Station consists of 363 acres, of which 170 are under long- and short-term experiments, 30 under nurseries, and 104 under special arable cropping designed to restore the uniformity of the soil of grubbed areas as a prelude to further experiments. The remaining 59 acres (being unsuitable for fruit), are under arable crops or used for roads, buildings, etc. Extensive laboratories, packing sheds, farm buildings, and greenhouses meet the needs of the expanded research staff, while Bradbourne House, in addition to the administrative staff, houses the Commonwealth Bureau of Horticulture and Plantation Crops.

The Station's original aim was to study the problems met with "in the culture and growth of fruit plants and hops" through the elucidation of the principles underlying cultural operations such as pruning, propagation, the use of rootstocks, manuring, cultivation etc. in relation to the growth and physiology of the tree. Strictly varietal studies were then, as now, excluded from the research programme which has, however, been steadily expanded to allow of increasing attention to the problems involved in the control of pests and diseases and to the maintenance of the health status of propagation material.

On 31st March, 1957 the scientific and experimental staff of the Station numbered seventy-five.

CURRENT WORK

Pomology. The work of this section involves study of the fruit plant in the field, its propagation, establishment, vegetative growth, flowering, and cropping; yield analysis; rootstock studies and selection; root anatomy and mycorrhizal relations; fruit and rootstock breeding for specific ends; spring frost damage and its alleviation; and pomological testing and multiplication of re-selections of known health status of important varieties of all types of fruit.

Statistics. The section carries out research into field and laboratory experimental design and layout. It is also responsible for sampling methods and, in conjunction with other sections, the interpretation of experimental data. Assistance, is also given to the National Agricultural Advisory Service, in respect of both the experiments of the Experimental Horticulture Stations and those initiated under the auspices of the Regional Experimental Committees, and to other research stations at home and overseas.

Physiology. The work comprises growth studies; the inter-relation of vegetative and reproductive growth; principles underlying scion-rootstock interaction and propagation phenomena, including research on auxins and inhibitors; seasonal accumulation and utilisation of the energy reserves of the tree. The Section works in close association with members of the Research Institute of Plant Physiology.

Biochemistry. This section undertakes research on selected organic constituents of fruit plants, especially of apple and pear in relation to growth, cropping, and disease resistance.

Fruit Nutrition. The research covers the mineral nutrition of fruit plants in relation to growth, cropping, soil and cultural treatments; seasonal water requirements; and mulching, cover cropping and storage treatments.

Plant Analysis. This section is responsible for the development, in conjunction with the Fruit Nutrition and Statistics Sections, of methods of sampling and of analysis to permit adequate estimation of the nutritional status of cropping trees; it also studies the distribution of mineral reserves in the plant and carries out analyses for other research sections.

Pathology. The work of this section includes research on the fungal and bacterial diseases of all fruit plants, and on Verticillium Wilt of hops, including host-parasite relations, control measures and spray techniques; identification and relationships of the virus diseases of fruit and hops; their effects on growth and cropping; their vectors (in collaboration with the Entomology Section) and alternative hosts; and isolation or production by heating or other therapeutic treatment of clonal re-selections of optimal health status of all important varieties of fruit and hops for ultimate release to the industry after pomological examination and preliminary multiplication.

Entomology. The work of this section covers the inter-relationship between fungicide and insecticide programmes and the balance of beneficial, of neutral, and of harmful members of orchard fauna; population studies; and control of orchard pests, aphids, ground beetles, *Tortricidae*, Jassids, eelworms of strawberry and of tree fruits.

Plant Protective Chemistry. This section studies the mechanism of action of selected insecticides. In addition, it deals with the improvement of spray programmes to permit of integrated chemical/biological control, laboratory and small-scale field techniques for the testing of fungicides and insecticides; phytotoxicity; and spray deposits.

Scientific Liaison. In addition to its other work, this section undertakes fruit storage investigations. Orchard factors affecting the storage life of apples are studied and storage tests are made on fruit grown under diverse environmental conditions in the various apple growing districts of Great Britain.

OUTCOME OF RESEARCH

Considerable attention has been given during the last decade to re-assessments of the relative importance of the problems of the fruit growing industry under changing conditions and to appropriate adjustments of the research programme. Ample opportunities for such re-assessment arise out of the direct representation of the industry on the Executive Committee of the Station, the frequent contacts between the staff and growers, and the arrangements for regular discussion with members of the 2,000-strong East Malling Research Station Association and with horticultural officers of the National Agricultural Advisory Service and other specialists. Further, the Station has taken a leading part in the preparation of three draft memoranda for the joint committee of the Agricultural Improvement Council and the Agricultural Research Council charged with defining and assessing the relative importance of the problems of the apple industry, of the soft fruit industry, and among others of the cherry, pear and plum industries, where additional research, or a change in the emphasis of research, could be expected to lead to advances of major economic importance.

An attempt to assess the results of recent research over the wide field of the Station's research programme, in terms of their economic applications, is likely to be invidious and, possibly, misleading. With this reservation, a few examples are given in the following paragraphs of work already proving or likely to prove of value to the country's fruit and hop growing industries.

An outstanding example has been the success of the Plant Pathology and Pomology Sections in making possible the Station's Mother Tree Scheme as a source of propagation material re-selected for freedom from virus diseases, for satisfactory pomological behaviour, and for known identity. Such foundation material is already available of six apple rootstocks and of one cherry rootstock, of eleven apple varieties, of fifteen cherry varieties, and of three pear varieties. The problems posed by the wide dissemination of virus diseases in the course of commercial propagation over the years have been recognised and defined and their economic importance demonstrated.

Of equal importance to soft fruit growers has been the foundation of the Nuclear Stock Association and the establishment, in conjunction with the National Fruit Trials, of a system for the isolation (or, if necessary, production) of healthy nuclei of tested pomological behaviour of all important strawberry varieties.

Hop growers have similarly benefited from the isolation of propagation material free of Progressive Verticillium Wilt.

The Pomology and Physiology sections have made possible, by improved methods for the large scale propagation of rootstocks by cutting, advances in nursery technique which have aroused great interest among leading members of the nursery trade. In addition, the introduction of the technique of double-budding has reduced to vanishing point the economic importance of the problem of rootstock-scion incompatibility in the propagation of many varieties of pears.

The Fruit Nutrition, Pomology, Scientific Liaison, and Plant Analysis sections have, by joint work, enabled considerable advances to be made in the understanding of the use of swards and mulches in orchards. Similarly recent developments have already provided information of importance upon the seasonal water requirements of top and soft fruits in relation to irrigation, and upon the effect of such orchard practices on the storage life of apples.

The Pathology and Biochemistry sections have broken new ground by studies of the part played by compounds naturally occurring in apple and pear in enabling the host plant to resist attack by the scab organism; these studies serve as a guide to the selection of chemicals of related structure for test as

possible fungicides and bactericides. Again, studies of nematode infections of top and soft fruit in the Entomology section hold promise on advance in the understanding of 'soil-sickness' and of replanting problems.

REPORT

Officers of the National Agricultural Advisory Service and members of the Association are kept fully conversant with the progress of research; in addition completed stages in the work are reported in a wide variety of scientific journals and in the Annual Reports of the Station. In order to make more readily available the results of completed research, a 40 year annotated index to the Annual Reports of the Station has been prepared during the last four years and is now in the press, while a chronological list, under subject headings, of papers published by the staff of the Station in other journals has been made available to libraries and research workers in related fields.

AGRICULTURAL AND HORTICULTURAL RESEARCH STATION Long Ashton, Bristol

Director: Professor T. Wallace, C.B.E., M.C., D.Sc., F.R.I.C., V.M.H., F.R.S.

POMOLOGY

Head of Department: L. C. Luckwill,
B.Sc., Ph.D.

D. L. Abbott, B.Sc.

E. W. Hobbs, B.Sc., N.D.H.

R. R. Williams, B.Sc., Dip.Hort.sci.

NUTRITION OF FRUIT CROPS

Head of Department: C. Bould, M.Sc., Ph.D.

D. G. Hill-Cottingham, M.Sc.

CHEMISTRY OF INSECTICIDES AND FUNGICIDES

Head of Department: J. T. Martin,
D.Sc., Ph.D., F.R.I.C.

E. J. Skerrett, Ph.D., A.R.I.C.

E. Somers, M.Sc., Ph.D.

W. D. E. Thomas, B.Sc., Ph.D., F.R.I.C.
(Physical Chemistry)

D. Woodcock, M.Sc., Ph.D., F.R.I.C.
(Organic Chemistry)

ENTOMOLOGY

Head of Department: H. G. H. Kearns,
O.B.E., B.Sc., Ph.D., Dip.Agric.

S. H. Bennett, B.Sc., Ph.D.

N. G. Morgan, B.Sc.

A. Stringer, B.Sc., A.R.C.S.

Secretary: A. L. Leggett, A.S.A.A.

PLANT PATHOLOGY

Head of Department: R. W. Marsh, M.A.
R. J. W. Byrde, B.Sc.(Hort.), Ph.D.

A. T. K. Corke, B.Sc., Ph.D.

PLANT PHYSIOLOGY

Head of Department: E. J. Hewitt,
B.Sc., Ph.D., A.K.C.

CIDER AND FRUIT JUICES

Head of Department: A. Pollard, M.Sc., Ph.D.

F. W. Beech, B.Sc., Ph.D., A.R.I.C.

L. F. Burroughs, B.Sc., A.R.I.C.

J. G. Carr, B.Sc., Ph.D.

Miss M. E. Kieser, B.Sc., A.R.I.C.

C. F. Timberlake, M.Sc., A.R.I.C.

G. C. Whiting, B.Sc., Ph.D.

DOMESTIC FOOD PRESERVATION

Head of Department: Miss B. A. Crang, B.Sc.
Miss M. Sturdy, B.Sc.

WILLOWS

Head of Department: K. C. Stott, B.Sc.

STATISTICS

Head of Department: G. M. Clarke,
M.A., Dip.stat.

SCIENTIFIC LIAISON

Head of Department: M. Greenwood,
O.B.E., M.Sc.

Librarian: Miss S. M. Beresford, B.Sc., A.L.A.

The Station originated as the National Fruit and Cider Institute, an independent body established in 1903 to promote improvements in cider-making and cider-orcharding. In 1912, on the recommendation of the Development Commissioners, it became associated with the University of Bristol as a State-aided station to undertake research into all aspects of fruit culture and to carry out advisory work in agriculture and horticulture in the Bristol province. Its development was hindered by the 1914-18 war, but by 1919 it had a staff of seven

Scientific Officers engaged on problems of cider-making, of orchard management, pest and disease control, fruit nutrition and plant breeding. The present farm of 257 acres was purchased in 1920 and between the wars the work of the Station steadily expanded.

On the outbreak of the Second World War, the Station's work was harnessed to the food production campaign. The Cider section investigated a number of fruit products, including black currant juice and rose hip syrup, in its search for sources of vitamin C for children; in Plant Nutrition attention was turned to farm crops and vegetables as well as fruit, and special staff were appointed to deal with the problems, many involving trace elements, which arose on newly ploughed land; the Pathology sections also studied the whole range of agricultural and horticultural crops, taking a prominent part in wireworm investigations and establishing a temporary laboratory at Evesham to deal with diseases and pests of vegetables; Dr. Kearns, of the Entomology section, became a leading adviser to the Ministry of Agriculture on problems of spray machinery. These war-time activities had an influence on the post-war programme; the Entomology section retained its interest in spray machinery and set up workshops for the design of improved machines, while the Nutrition section continued its studies of the effects of trace elements on plant nutrition. But today most of the special wartime investigations have been concluded and a comprehensive programme of fruit research is being carried out.

The post-war building programme has been inadequate to cope with the increased number of staff. A single-storey Biology building, to house the Pathology Sections, was completed in 1948. Plans comprising a block of laboratories and offices, canteen and common-room, and a block of greenhouses with attached special-purpose laboratories, were prepared in 1950. The greenhouse block was completed at the end of 1956, but the erection of the remaining buildings is yet to begin. Congestion has been partially relieved by the temporary conversion of the store of the Biology building to laboratories and offices in 1953 and by the provision in 1956 of a small laboratory to serve the Spray Analysis team and for the biochemical work of the Unit of Plant Nutrition.

On the 31st March, 1957 there were seventy scientific and experimental staff at the Station.

CURRENT WORK

Fruit Nutrition. Long-term fertiliser trials are taking place at Long Ashton and, in collaboration with the National Agricultural Advisory Service, at the Luddington, Efford and Rosewarne Horticultural Experiment Stations, to study the relationship between growth, yield and leaf nutrient status in fruit crops and the effect of cultural systems, including cover-crops, on tree fruits. Laboratory and field investigations of iron chelates for the control of lime-induced chlorosis are also in progress.

Pomology and Plant Breeding. The work includes the breeding of improved varieties of black currants and cider-apples; the cultivation and classification of gooseberries; studies of auxin production in apple and black currant; the use of synthetic growth substances for the control of pre-harvest drop and orchard weeds, and as thinning agents for apples and plums; dormancy in apple seeds; the development of apomictic seedling rootstocks; virus diseases of tree fruits and rootstocks; and surveys of cider apples and perry pears and investigations of their pollination requirements.

Chemistry. The main items of the current research programme are:—

- (a) *Organic.* The chemistry of plant growth regulators; the metabolism of organic compounds by fungi; and the relationship between structure and biological activity of insecticides and fungicides.

- (b) *Physical*. The application of radioactive tracers to investigations of growth-regulating substances, of phosphate metabolism in higher plants, of the behaviour of copper fungicides on leaf surfaces, of the movement of chelates in soil and of the role of iron and molybdenum in the metabolism of micro-organisms; and the study of the physical properties of sprays in relation to their efficiency and retention.
- (c) *Analytical*. The development of methods of analysing spray deposits in order to study their distribution and retention in relation to their efficiency and to consumer hazards; and the examination of plant waxes in relation to varietal resistance to disease and the retention of spray materials.

Entomology. The section is carrying out laboratory and field experiments to study the effects of droplet size and distribution of spray fluids and host plant characters on the biological efficiency of sprays. The effects of variety and cultural practices on susceptibility to insect attack are being investigated; bioassays and studies of the mode of action of insecticides are being made.

Pathology. Studies are being made of the biology of pathogenic fungi, including those causing apple scab, *Gloeosporium* rot, brown rot, mildew, canker and currant leaf-spot, and their host-parasite relationships. In addition there are laboratory studies of the mode of action of fungicides, and field trials at Long Ashton and Luddington of their efficiency in controlling diseases and storage rots and of their effect on the processing qualities of fruit.

Cider and Fruit Juices. In this field the work includes the determination of the chemical composition of varieties of cider apple and perry pear and of the changes taking place during juice fermentation; processing operations in cider and perry making; the classification and metabolism of micro-organisms occurring in apple juices and fermented products; the preparation and storage of apple juice concentrates and soft fruit syrups; and the estimation of metals occurring naturally or as contaminants in juices and ciders.

Domestic Food Preservation. This section undertakes tests of varieties of fruit and vegetables for their suitability for bottling, canning or deep freezing; heat penetration studies to study the safety of methods of preserving fruit, vegetables, meat and poultry; the checking of official publications of recommended methods; the examination of packaging material for the deep freezing of fruit, vegetables, meat and poultry; effects of spray treatment on quality of fruit.

Willows. The work comprises investigations of the rooting habits of basket willows; study of the effects of spacing and cultural operations on yield and quality; the control of weeds, pests and diseases; the classification of basket willows; and anatomical studies of cricket bat willows.

Statistics. The work includes biometric studies, including methods of sampling trees and bushes for determination of quality, composition, disease infestation, etc.; the correlation of vigour with crop weight in soft fruits; analysis of experimental data and the design of field and greenhouse experiments.

OUTCOME OF RESEARCH

Through its Cider Advisory Committee the Station has kept the cider grower informed of developments in the industry and of likely trends in the demand for fruit; it has regularly published recommended lists of cider varieties of proved vintage quality and of known orchard performance and pollination requirement. The cider maker has been shown new techniques for handling varieties liable to spoilage during fermentation and has been instructed in hygienic methods of production. Important investigations have been made of the storage conditions required for apple juice concentrates and for black currant syrup, a product first

developed at Long Ashton. The part played by copper in promoting storage hazes has been shown, and contamination by other metals has been studied.

The recognition of nutrient deficiencies in agricultural and horticultural crops has been facilitated by the publication of a colour atlas and by the development of rapid chemical tests for the examination of plant tissues. The specific nutrient requirements of apple, black currant and strawberry have been determined in conjunction with leaf analysis, which has also been used to show the enhanced availability of potassium and phosphate that results from the grassing-down of orchards and the value of foliar sprays of urea in supplying the extra nitrogen needed during the establishment of a grass cover. Foliar sprays and soil applications of iron chelates have shown great promise for the control of lime-induced chlorosis in fruit trees.

In its study of auxins in developing fruits the Pomology section has established the relationship between auxin production and fruit drop in apples and black currants. The mechanism of chemical fruit thinning has been elucidated and synthetic growth substances have been applied to the chemical thinning of fruit and to the control of annual weeds in nurseries and of Bindweed in black currant plantations. The discovery that the virus of rubbery wood is widely distributed in latent form in clonal apple rootstocks is of particular importance. While the black currants Cotswold, Mendip and Malvern Crosses, and the pear Bristol Cross, are the best known of the fruits bred at Long Ashton, two early dessert-apples, Cheddar Cross and Exeter Cross, are now attracting the attention of growers.

In conjoint work in plant pathology the merits of new materials for the control of pests and diseases have been assessed; recommendations have included the substitution of BHC/DDT spring washes for ovicidal winter washes and of captan for lime-sulphur to control scab. Improved methods of formulation and application of spray materials have been devised to effect economy and greater efficiency in their use. Besides standard methods of analysis to ensure that growers receive materials conforming with official specifications, micro methods have been developed to study the distribution and retention of materials on plant surfaces and the likelihood of consumer hazards; radioactive studies of systemic insecticides have shown their movement in plants and the duration of their effect. The application of eradicant fungicides in the dormant season promises further advances in the control of black currant leaf spot and in joint trials with the Ditton Laboratory it has been shown that orchard applications of organic fungicides can reduce the incidence of storage rots by two-thirds.

Amongst spray machinery designed at Long Ashton may be mentioned air-flow mist blowers of which one model has been in use for locust control in East Africa since 1950, the Long Ashton spray nozzle, automatic sprayers for pyramid apples and black currants and various light-weight engines for use in the tropics.

Advisory work on the control of pests and diseases has been carried out with rubber in Malaya, bananas in Jamaica, coconuts in Zanzibar, cotton and other crops in East Africa, the Solomon Islands and Borneo.

The Domestic Preservation section has regularly published bulletins embodying its latest recommendations for the preservation of different varieties of fruit and vegetables and since 1930 it has held annual courses for the instruction of staffs of local authorities and other recognised teachers of domestic science. Investigations of the preserving of meat and poultry undertaken in 1953 at the request of the Ministry of Food have resulted in the preparation of a bulletin of recommended methods, now being printed.

The Willows Officer is responsible for advisory work in Great Britain and receives many requests for cuttings from the Station collection of basket willows which now includes 180 varieties. Surveys of the Lancashire and Somerset willow growing areas have recently been completed.

Fuller details of the work are given in the Station's Annual Report.

A.R.C. UNIT OF PLANT NUTRITION (MICRO-NUTRIENTS)

Long Ashton, Bristol

Honorary Director: Professor T. Wallace, C.B.E., M.C., D.SC., F.R.I.C., V.M.H., F.R.S.
(Professor of Horticultural Chemistry, Bristol University)

Senior Scientific Staff

PLANT PHYSIOLOGY

E. J. Hewitt, B.SC., Ph.D., A.K.C.

NUTRITION OF MICRO-ORGANISMS

D. J. D. Nicholas,
B.SC., Ph.D., A.K.C., F.R.I.C.

SOIL BIOLOGY

R. A. Webb, B.A., D.Phil.

ORGANIC CHEMISTRY

A. H. Williams, M.A., B.SC.

PLANT BIOCHEMISTRY

H. E. Davenport, B.SC., Ph.D.
H. M. Stevens, B.SC., Ph.D.

The Unit was established by the Council in 1952 to investigate problems relating to the functions of micro-nutrients in the growth of plants and micro-organisms. It was formed to continue on a more permanent basis investigations that had developed from the wartime researches of a small group of workers, under the direction of the Honorary Director, concerning special problems of crop production related to micro-nutrients.

During the war the researches of the team had been wholly concerned with the solution of practical field problems, and had shown the importance of deficiencies and excesses of several mineral elements, other than nitrogen phosphorus and potassium, in crop production. In particular, the importance of deficiencies of calcium, magnesium, iron, manganese and boron and excesses of heavy metals had been demonstrated and methods developed for their control. After the war these practical investigations had been extended to deficiencies of copper, zinc and molybdenum, and methods for the control of these had been evolved. The importance of the methods developed for the diagnosis of the mineral status of crops during the course of this work was early recognised by the Council, who sponsored the publication of a Colour Atlas and Guide to mineral deficiency symptoms in crops, first prepared by the Honorary Director in 1943 as a wartime edition for advisory officers and farmers, and later published in an extended and more comprehensive form in 1951.

These essentially practical investigations had been based on refined methods developed at Long Ashton, for the growing of plants as sand cultures, and led naturally to more fundamental studies of the role of the micro-nutrient elements in plants. This work necessitated greatly extended facilities and the provision of elaborate equipment to produce plants of known mineral status, for use in highly specialised biochemical and biological studies. These increased facilities were made available on the formation of the Unit.

On 31st March, 1957 the scientific and experimental staff of the Unit numbered twenty-five.

CURRENT WORK

Plant Physiology. The role of molybdenum in the metabolism of higher plants is being studied. In laboratory and pot culture studies the role of molybdenum in nitrate reductase has been confirmed and a relationship with the production of ascorbic acid established.

The investigations have been linked with field experiments on crops, particularly cauliflower and lettuce, which are very susceptible to molybdenum deficiency in the field.

Biochemistry of micro-organisms. Investigation is being made of the role of micro-nutrients in nitrogen metabolism, in the processes of reduction of nitrate to ammonia and the fixation of nitrogen by soil bacteria. These studies on micro-organisms have been especially fruitful; in particular the roles of micro-nutrient metals in all steps of the reduction of nitrate to ammonia (—nitrate—nitrite—hyponitrite—hydroxylamine—ammonia) have been elucidated. This work is likely to have many applications in microbiology and is already being applied in various studies at Long Ashton, in the determination of the availability to plants of micro-nutrients in soils (*Aspergillus* method) and studies of the enzyme systems involved in fungicide and pesticide/fungus/host plant relationships.

Biochemistry of haem-protein compounds in chloroplasts. Biochemical studies of these compounds in relation to micro-nutrient deficiencies are in hand. They are essentially directed to the solution of difficult metabolic problems concerning chlorophyll and related compounds and are not likely to produce early results.

Organic Chemistry. The subjects of investigation are the basic organic constituents of tomato plants and their relation to micro-nutrient status, and the polyphenols of fruit plants. The work is designed to produce basic data on important groups of plant products likely to be of importance in the biochemical studies. Thus in work on amino acids it was shown that low values were obtained in molybdenum-deficient plants, which pointed to abnormal conditions of nitrate reduction; this was later confirmed by the discovery of the role of molybdenum in nitrate reductase. The investigations on the polyphenolic compounds in apple and pear tissues also showed that these tissues could be differentiated by special polyphenols—phloridzin in apple and arbutin in pear. This finding may have applications in studies of stock/scion relationships, taxonomy and characterisation of hybrid species.

Inorganic Chemistry. The investigations involve the determination of valency states of micro-nutrients in plants with reference to their role in enzyme systems. The results have been successfully applied in studies of the valency changes undergone by molybdenum in nitrate reductase systems.

Soil Chemistry and Biology. In this section special pot culture and field experiments have been carried out in the Gambia which promise to throw light on the mineral nutrient problems of tropical soils and crops of that area. The methods used, based on the original Long Ashton pot culture techniques, are also being applied by Agricultural Officers in other parts of the African Colonial Territories and, on a comprehensive scale, on tropical crops at the West African Institute for Oil Palm Research and the Rubber Research Institute of Malaya, with whom close liaison is maintained.

SCOTTISH HORTICULTURAL RESEARCH INSTITUTE

Mylnefield, Invergowrie, by Dundee

Director: T. Swarbrick, M.Sc., Ph.D.

PLANT PATHOLOGY

Head of Department: C. H. Cadman,
B.Sc., Ph.D., F.R.S.E.

VEGETABLE CULTURE

Head of Department: C. North,
B.Sc., M.Sc., Ph.D.

POMOLOGY

Head of Department: C. A. Wood,
B.Sc., Ph.D.

CROP PHYSIOLOGY

Head of Department: C. L. Hodgson,
M.A., D.Phil.

MYCOLOGY

Head of Department: A. R. Wilson,
B.Sc., M.S., Ph.D.

WEST OF SCOTLAND UNIT

Auchincruive, Ayr.
R. D. Reid
Miss I. G. Montgomerie, B.Sc., Ph.D.

Secretary: A. B. Ross, A.I.A.C.

The Institute was established as a grant-aided research centre as recently as the Spring of 1954. The need for such a research centre had been recognised for some time and in 1946 the Department of Agriculture for Scotland set up a " Horticultural Research Committee " to establish it. Unexpected difficulties arose in finding a suitable area of land for the purpose, but eventually Mylnefield Farm near Dundee, was secured and development of the site began in Spring 1951, when the present Director, Dr. T. Swarbrick, took up duty as Director of Horticultural Research in Scotland. The Institute is governed by a board appointed by the Secretary of State for Scotland.

After much discussion it was agreed that instead of small separate research centres devoted to fruit, vegetables and glasshouse crops there should be a unified horticultural research organisation in Scotland. The main centres of horticultural production are, however, widely separated in the Perth-Angus, Clyde Valley and East Lothian areas. It was decided to develop the main research centre at Invergowrie, with a West of Scotland Unit at Auchincruive, Ayr, and to leave open for the future the possibility of other sub-units in the Lothian and Moray Firth areas.

The Scientific and Experimental staff at the Institute on 31st March, 1957 numbered twenty-five.

The problems investigated by the Institute arise directly from the Scottish horticultural industry, although their solution should contribute to improved commercial practice wherever fruit and vegetables are grown under somewhat similar conditions. Although the climate of Scotland may preclude the development of a large-scale top fruit industry it favours soft fruit and many vegetables and the research programme therefore concentrates on soft fruit and vegetables, though not to the exclusion of top fruit.

CURRENT WORK

Virology. Because of the importance of virus diseases a strong department of virology is being built up and a result already achieved is the production of small stocks of virus-free plants of most of the commercial varieties of raspberry. The use of these in commercial propagation should result in higher annual yields and plantation life as compared with longer existing stocks. The work done in this field by the fruit research stations has provided the basis for the official raspberry and strawberry certification schemes now in force throughout the United Kingdom. More recently it has been found that certain virus diseases of fruit and other crops are soil-borne.

Pomology. The practical aspects of fruit culture are investigated by this department. These include the relative merits of a wide range of varieties, manuring, pruning and training methods. Thus it has already been shown that four varieties of raspberry may be expected to outyield all others under similar conditions. An important part of the department's work is the breeding of new varieties of raspberries, strawberries and black currants. The strawberry breeding work which is carried out at the West of Scotland Unit has already produced the varieties Climax, Talisman and Redgauntlet, all of which have found commercial acceptance not only in this country but overseas, particularly in Holland, Australia and New Zealand.

Vegetable Culture. This department, in addition to carrying out many variety trials, has a substantial breeding programme. This programme, which uses hardy strains from Northern Scandinavian countries as parent material, aims at improved and hardier Brussels sprouts and winter-heading cabbage.

Mycology Section. The department is concentrating mainly on the diseases caused in raspberries, strawberries, tomatoes and lettuce by the fungus *Botrytis*. In some seasons raspberry yields in Scotland are reduced by this fungus by upwards of one ton of fruit per acre, or about £100 in value.

Crop Physiology. The department is attempting to analyse and specify the more important factors affecting plant growth in the climatic complex of Scotland, which is very different from that of, say Kent or the West Midlands. This work also involves studies of the effect of climate on the initiation and development of fruit buds and stolons in the strawberry.

Genetics. The department is concerned primarily with the problem of "June Yellows" in the strawberry, which current thinking regards as being due to abnormalities in the cytoplasmic organisation as distinct from that of the chromosomes. The possibilities of inducing desirable mutations by the use of nuclear radiation are also being studied.

OUTCOME OF RESEARCH

With only five years' work behind it the Institute can, understandably, claim only modest contributions to improved commercial practice. The departments of Virology, Pomology, Vegetable Culture and the West of Scotland Unit are now well established and are contributing in various ways to improved horticultural practice. Virology has provided virus-free stocks of a number of varieties and has shown how important it is to plant only material of high health status. Pomology has shown that some varieties will always outyield others and that, in order to obtain high yields of good quality fruit, certain cultural practices must be observed. The West of Scotland Unit has released two new strawberry varieties, one in 1955 and the other in 1957. The Vegetable Culture department has shown that by the use of suitable varieties, spinach and French beans can be grown commercially in Scotland and promising new varieties of sprouts, cabbage and French beans are undergoing trial.

The main results of the Institute's work are set out each year in its Annual Report.

WYE COLLEGE

Department of Hop Research

Wye College (University of London), Ashford, Kent

Head of Department: H. S. Darling, B.Sc., M.Agric., A.I.C.T.A.

Senior Scientific Staff:

F. C. Thompson, B.Sc., M.Sc.Agric., A.R.I.C.

R. A. Neve, B.Sc.Agric., Dip.Agric.sci.

Research on hops has been in progress at Wye College since the turn of the century. In 1947 the arrangements for doing this work were reorganised and a separate Research Department established at the College. The Department is administered by the College with technical guidance from the Agricultural Research Council and financial aid from that body and the hop growing and brewing industries.

Departmental investigations cover all aspects of hop production except virus diseases and the pathology of *Verticillium* wilt, research on which is in progress at East Malling Research Station. In the current research at Wye, the emphasis is laid on plant breeding, plant nutrition and cultural problems. Attention is also being given to picking and drying in connection with the development of mechanisation (in collaboration with the National Institute of Agricultural Engineering), to the organic chemistry of the hop plant and to the control of pests; research on hop downy mildew disease has restarted after a lapse of twenty years. The Department at present has a scientific and experimental staff of nine.

VEGETABLES

NATIONAL VEGETABLE RESEARCH STATION

Wellesbourne, Warwick

Director: James Philp, B.Sc., Ph.D.

PLANT BREEDING

Head of Department: J. C. Haigh,
B.Sc., Ph.D., A.R.C.S., A.I.C.T.A.

IRRIGATION

Head of Department: E. J. Winter,
M.C., M.Sc.

PATHOLOGY

Head of Department: W. G. Keyworth,
B.Sc., Ph.D., A.R.C.S., D.I.C.

CHEMISTRY

Head of Department: F. Haworth,
B.Sc., Ph.D., Dip.Ag.Sci., A.R.I.C.

ENTOMOLOGY

Head of Department: D. W. Wright, M.A.
J. A. Dunn, M.Sc.
G. A. Wheatley, B.Sc.

WEEDS

Head of Department: H. A. Roberts, B.Sc.

STATISTICS

J. A. Nelder, M.A.

Secretary: J. C. Wilkins, Ll.B., F.C.I.S.

Librarian: Miss B. M. Baggs, M.Sc.

The Station at Wellesbourne, Warwickshire, and its Sub-Station at Paglesham, Essex, were established in 1949. The headquarters Station consists of 280 acres of sandy loam suitable for field experimental work with vegetables. Farm buildings, glasshouses and services have been provided, and a block of permanent laboratories and offices is now being built. There are eight research sections which deal with the breeding of improved varieties of vegetables, the improvement and maintenance of soil fertility, the factors affecting crop growth, the study of irrigation and the control of pests, diseases and weeds.

The Sub-Station at Paglesham consists of 150 acres of fertile loam. The climate and other conditions in Essex account for its being the main vegetable seed producing area in England. The main purposes of this Sub-Station therefore are the multiplication of seed of vegetables bred by the Research Station and the investigation of problems peculiar to this line of work.

The Station enjoys the co-operation of the National Agricultural Advisory Service Experimental Horticulture Stations and of the National Institute of Agricultural Botany in the testing of its findings and of potential new varieties in different areas. Results should be obtained, therefore, which will be applicable to the conditions in different regions and thus the Station will provide a service on a national scale to growers of vegetables, to others associated with this work, and to consumers of their products.

On 31st March, 1957, the scientific and experimental staff of the Station numbered thirty-six.

CURRENT WORK

Plant Breeding. The main breeding problems upon which the section is working are—

<i>Crop</i>		<i>Object of work</i>
Asparagus	...	To produce a strain of seed which will give only male plants.
Brussels sprouts	...	To improve uniformity, yield and quality.
Cauliflower	...	To improve earliness and curd quality of the variety Cambridge No. 5.
Lettuce	...	To produce a variety or varieties of summer cabbage lettuce resistant to mosaic virus disease, downy mildew, Botrytis and tip burn.
Onion	...	To develop uniform, early maturing, high yielding F_1 hybrid varieties.
Pea	...	To produce an early maturing wrinkled pea, hardy enough for early sowing.
Radish	...	To develop a variety of improved uniformity and which is not inclined to become pithy.
Red beet	...	To produce a globe beet variety which has a good colour, does not bolt when sown early and has a single-seeded fruit.
Spring cabbage	...	To produce a dual-purpose variety suitable for either spring greens or hearted cabbage.

In the course of the work, synonymy studies have been made with lettuce, radish, red beet and spring cabbage. Breeding techniques for certain brassicas, and the causes of deterioration of brassica varieties are being investigated in Brussels sprouts. The section is also responsible for maintaining supplies of nucleus stock seed of the Cambridge varieties of vegetables which have already been marketed and were bred by the Horticultural Research Station formerly in existence in Cambridge. This seed is multiplied for one generation by the National Institute of Agricultural Botany and subsequently by the Seed Trade and others for commercial distribution.

Chemistry. Long-term field experiments are in progress on the effects on the soil and on the crop (using different rotations of vegetables) of the following

treatments in various combinations:—deep and shallow ploughing, sub-soiling and rotavating; applying fertilisers in various ways, times and quantities; organic and inorganic manures; with and without farmyard manure; rates of application and different combinations of the main nutrients, nitrogen, phosphorus and potassium. These experiments provide material for studies of the effects of the treatment (*a*) on the soil, as regards availability of nutrients, rate of mineralisation of organic nitrogen, and organic matter status; and (*b*) on the crops, as regards mineral status and organic constituents throughout the growing season.

Plant Physiology. Physiological studies have been started on the development of the pea crop as it is affected by different nutritional and cultural treatments in the field. The germination capacity and vigour of onion seed are most variable and strongly influence crop yield. Possible causes of variability are under investigation. Tests are being carried out on methods of production of onion sets, and on varieties for their suitability for use as onion sets. With the object of producing pickling onions of improved quality in this country, experiments are in progress on varieties and cultural treatments in collaboration with the British Food Manufacturers' Research Association. The extent of competition between vegetable crops and annual weeds is being assessed, and means of shifting the balance in favour of the crop are being tested. The spacing of crops and the timing of weeding operations are receiving special attention. Factors affecting the growth and flowering of watercress are under investigation in order to solve a practical problem which has arisen from the production of virus-free watercress from seed.

Irrigation Section. Studies are being made of the effects of different soil moisture treatments on the germination, establishment, growth, yield and quality of various vegetable crops in the field. The effects of applying water to vegetable root crops at different stages in growth are also being studied. Investigations are in progress on evapo-transpiration rates from different crops as an aid in determining the amount of water to be applied when irrigating these crops. Comparisons are also being made of the effects of spray irrigation with those of furrow irrigation.

Entomology. The extent of damage to the yield and quality of brassica crops caused by the cabbage root fly, and the degree of control achieved by different treatments with soil insecticides are being assessed. Studies are also being made of the interactions between insecticides and predators, of their effect on the population of the cabbage root fly and of the seasonal effect on these interactions. Work is continuing on the development of techniques with insecticides which will give an improved control of carrot fly. Incorporation of insecticides in the soil is being tested for its efficiency in controlling the pest, for its effect on the flavour of the carrots and on succeeding crops in the rotation, and on predators of the pest. The use of insecticides and modifications in cultural methods are being studied with a view to finding methods of controlling carrot fly attack on parsnips. Insecticides are being tested for the control of lettuce root aphid. Some varieties of lettuce, however, have been found to be resistant to attack. A method of determining the date of emergence of pea moth is under investigation in order to ensure that spray treatments are applied at the correct time.

Plant Pathology. Studies have been made on the fungus which causes crook root disease of watercress and on methods of controlling the disease. Studies are also being made of the effect of virus infection on the yield of watercress, of the strains of the virus and of the vectors of this disease. It has been shown that virus-free stocks of green cress can be grown from seed. Silvering disease of the seed crop of red beet has been shown to be caused by a new species of bacterium which is seed-borne. Methods of controlling are under investigation. Stem rot

disease of outdoor tomatoes caused by the fungus *Didymella* is being studied with a view to finding methods of preventing its occurrence and of controlling it.

It has been found that either of two fungi can cause parsnip canker in this country and work is continuing in order to find a control method. Some strains of parsnip showing resistance to the disease have been obtained by selection. Investigations are being made with the object of finding means of controlling club root disease of brassicas. A variety of cabbage has been obtained which, although of poor quality, shows some resistance to club root and it is being used as a parent in breeding work.

Weeds. An ecological study is in progress of important weeds of vegetable crops in relation to the conditions imposed by the growing of these crops. This knowledge is needed to facilitate the development of weed control methods, both culturally and chemically. A study is also being made of the effects of promising new herbicides on growth, yield and quality of vegetable crops, and of climatic and other factors affecting the success of herbicidal applications.

Statistics. Advice on the design of experiments and analysis of results is given by the Statistics section to other sections and also to certain outside bodies. Investigations are in progress on the relative contributions of various factors to experimental error in vegetable experiments and on the analysis of hereditary characters showing continuous variation.

OUTCOME OF RESEARCH

Methods of controlling cabbage root fly on brassica crops have been developed and are in general use. This pest, therefore, should not now cause any problem. The Station has also developed techniques for the application of insecticides to the crop or to the seed which give a large measure of control of carrot fly on carrots. Seed treatment with insecticide has also given effective control of carrot fly on parsley.

It has been demonstrated that DDT gives excellent control of leaf miner and pea moth in peas and zinc frit (powdered glass containing zinc) has been shown to control crook root disease of watercress.

Steeping red beet seed in a solution containing the antibiotic, streptomycin, has given almost complete control of silvering disease of the succeeding seed bearing crop. Streptomycin is not commercially available, but an organo-mercurial dust has been found to be fairly effective.

It has been possible to recommend precautions to prevent attack of outdoor tomatoes by the fungus *Didymella*, and certain fungicidal sprays have given a promising degree of control. Spray treatments with Thiram have been shown to give good protection against botrytis disease of winter lettuce and Monuron has been found to be a valuable herbicide for the control of annual weeds in both seed beds and established beds of asparagus.

It has been shown also that Dinoseb (amine) is an effective herbicide for the control of annual weeds in market garden peas.

As might be expected with a young Station, the practical findings all concern the control of pests, diseases and weeds. Practical results from the long-term work of the other sections of research are unlikely to be obtained for some time. Some of the more advanced lines of investigation have, however, already shown considerable promise. While the work of the Station is directed towards the solution of important practical problems, the applied research on each problem is balanced by a proportion of fundamental work which is essential for progress on the applied side.

Further information on the work of the Station can be obtained in the Station's Annual Reports.

WEEDS

A.R.C. UNIT OF EXPERIMENTAL AGRONOMY

Department of Agriculture, University of Oxford

Honorary Director: G. E. Blackman, M.A. (Sibthorpe Professor of Rural Economy, Oxford University)

Assistant Director: E. K. Woodford, M.Sc., Ph.D., D.I.C.

SELECTIVE TOXICITY AND HERBICIDAL ACTION

J. G. Elliott, M.A.

J. D. Fryer, M.A.

K. Holly, B.Sc. (Agr.), Ph.D.

C. C. McCready, M.A., D.Phil.

Miss D. J. Osborne, M.Sc., Ph.D.

R. G. Powell, B.A.

Miss L. Reinhold, M.Sc., Ph.D.

NEW CROPS—PARTICULARLY OIL SEED CROPS AND HYBRID MAIZE

E. S. Bunting, B.Sc.

Before 1950 the Council provided annual grants to the University of Oxford for research on the control of weeds by chemical means and on the development of special crops. To ensure continuity of this work and intensify fundamental research in agronomy, the Council in 1950, in collaboration with the University of Oxford, established the Unit of Experimental Agronomy. In view of the relevance of the research to tropical problems the Colonial Office undertook to meet part of the cost.

It was also clear that if research workers and advisory officers in Great Britain and the Colonies were to be kept fully informed there was a need to collate the flood of technical literature resulting from a world-wide expansion of work on selective herbicides, which had opened a new branch of agricultural science. An Information Section was, therefore, formed and the the Ministry of Agriculture, Fisheries and Food appointed a National Agricultural Advisory Service Liaison Officer to the Unit.

Since the Unit was formed the basic plan of the research programme has remained substantially the same, but there has been some change of emphasis as extra facilities have become available. The completion of the University Field Laboratory made possible the testing of new herbicides in pot culture. More recently, with a grant from the Colonial Office, a special "tropical" greenhouse has been built so that pot culture tests can be extended to cover tropical crops and weeds.

The Unit is organised into six sections:—

- (a) Information; collection and dissemination of research information;
- (b) Chemistry; organic syntheses, radio-chemistry of isotopically "labelled" materials and routine analytical work;
- (c) Plant physiology; mode of action of herbicides;
- (d) Pot culture and greenhouse; primary evaluation of new herbicides;
- (e) Field evaluation; evaluation in collaboration with the N.A.A.S. and other organisations;
- (f) New crops; introduction and development of crops new to Great Britain.

On 31st March, 1957 the scientific and experimental staff of the Unit numbered twelve.

CURRENT BASIC RESEARCH

The research programme over the last seven years has been founded on the tenet that when a physiologically active compound is applied either to the soil or to the foliage the reaction of individual species will depend upon a combination of some or all of the following factors:—

- (a) uptake by the root;
- (b) spray retention by the shoot;
- (c) penetration into the shoot;
- (d) transport within the plant;
- (e) localized accumulation; and
- (f) mode of action at cell level.

Work on all these aspects has therefore continued during the year.

Investigation of the mechanism of the uptake of herbicides by plant roots and their entry through the surfaces of floating aquatic weeds has shown that changes in the rate of uptake of phenoxyacetic acids (labelled with isotopic ^{14}C) during the first 1–2 hours are as expected for nutrient ions, but that during the next few hours uptake often ceases and is followed by an active excretion to the external solution. In a completely different approach it has been shown that the uptake of amino acids by sections of sunflower epicotyls is markedly increased as a result of treatment with indoleacetic acid.

The polar transport of variously substituted phenoxyacetic acids in excised segments of petioles and stems, using tracer techniques and ^{14}C carboxy labelled growth substances, has shown that 2:4 dichlorophenoxyacetic acid (2, 4-D) is transported by a system which differs from phloem transport in being much slower, highly polar, and apparently independent of carbohydrate movement. It is also highly selective, phenoxyacetic acids closely similar in chemical structure being moved in widely different amounts.

Studies on the mode of action of herbicides that act like auxins, and on the physiological effects of N, N-dimethyl-N-phenylurea (fenuron) and other substituted ureas, have continued. In addition, research on the characterisation and isolation of the abscission-inducing factor, discovered in senescent leaves, has been pursued at Oxford and in the tropics.

The pot culture and greenhouse investigations have been concerned primarily with the initial evaluation of a range of potential herbicides. One of the most interesting of these, 2-chloro-4, 6-bis (ethylamino)-S-triazine (simazin) is being studied in detail to determine how factors such as soil moisture, organic matter and depth of sowing, affect its toxicity and selectivity to different species. Research on the theory and performance of mixtures of herbicides is being extended. In addition, the evaluation of chemicals for the selective control of the important tropical parasitic weed, *Striga hermonthica*, has been started.

CURRENT FIELD RESEARCH AND DEVELOPMENT

Herbicides. Field investigations are concerned first with the measurement of the toxicity of herbicides to crops and weeds growing individually and in association, and then with the integration of these findings into farming practice. The main emphasis during 1957 was on 2-methyl-4-chlorophenoxybutyric acid (MCPB) and 2, 4-dichlorophenoxybutyric acid (2, 4-DB) and the new herbicides (2-methyl-4-chlorophenoxypropionic acid and monochloroacetic acid) introduced for the control of weeds of cereal crops that are resistant to 2, 4-D and 2-methyl-4-chlorophenoxyacetic acid (MCPA). In addition further trials were carried out with 2, 2-dichloropropionic acid (dalapon), 3-amino-1, 2, 4-triazole, simazin and several other new herbicides.

New Crops. Investigations on oilseed crops (poppy, linseed and rape) and hybrid maize have been continued. A four-year cycle of investigations on the factors influencing the yield of seed and capsule material in *Papaver somniferum* has been completed. The crop is now grown commercially on a limited acreage, mainly in East Anglia; yields of seed are somewhat erratic and the future development of the crop in this country is likely to be based on the production of both seed and morphine. Varietal differences in morphine content have been established and a breeding and selection programme initiated. The possibilities of winter rape as an oil seed crop for this country have been further explored and an account published.

The research on maize relates primarily to the general agronomy of maize as a silage or grain crop. The value of selected hybrid varieties for silage production has been demonstrated. Selection for early grain maturity continues while further new European hybrids of the grain type have been examined.

A.R.C. UNIT ON PLANT GROWTH SUBSTANCES AND SYSTEMIC FUNGICIDES

Wye College (University of London), Ashford, Kent

Honorary Director: Professor R. L. Wain, D.Sc., Ph.D., F.R.I.C.

(Professor of Agricultural Chemistry and Head of Department of Agriculture)

Senior Scientific Staff:

C. H. Fawcett, M.Sc., Ph.D., A.R.I.C.

R. A. Heacock, B.Sc., Ph.D.

F. Wightman, B.Sc., Ph.D.

The Unit was created in 1953 with the object of broadening the fundamental investigations on plant growth-regulating substances and systemic fungicides, which had been developing in the Chemistry Department of Wye College under the direction of the present Honorary Director.

The Unit contains chemists and biologists who collaborate closely in both the main lines of investigation proceeding within the Unit. Furthermore, several members of the University teaching staff are actively associated with the Unit and have made considerable contributions towards the progress of its work.

The accommodation provided by the College consists of research laboratories for chemistry, plant physiology and plant pathology with a constant temperature growth room and ancillary rooms for special operations such as chromatography, electrophoresis and infra-red spectroscopy. There is also a building equipped with precision spraying apparatus and humidity chambers and there are three small research glasshouses.

On 31st March, 1957 the scientific and experimental staff of the Unit numbered six.

CURRENT WORK ON PLANT GROWTH SUBSTANCES

The discovery, during the war, of these highly potent chemicals and their uses for increasing crop production has proved to be one of the greatest developments in agriculture during the past two decades. Fundamental studies can play an important part in the search for new growth substances with specific agricultural uses and also in elucidating the mechanisms by which these substances exert their growth-promoting effects.

Within the Unit considerable attention has been given to structure/activity relationships in the aryl- and aryloxyalkanecarboxylic acid series. This work, which has involved the synthesis of many hundreds of compounds and an

assessment of their growth-regulating activity by a number of test methods, has established the importance of certain structural features in relation to activity. Detailed studies have been made on the influence of nuclear and side-chain substitution, particularly in the aryloxy acids and their derivatives. Investigations on the importance of steric factors have revealed that in optically active growth substances specific physiological activity can be shown by one enantiomorph and not by the other. Such findings led logically to a hypothesis on the mode of action of compounds of this type and to investigations on competitive antagonism, the findings of which have already found application in tissue culture investigations carried out in collaboration with American workers.

Studies on the behaviour of natural and synthetic growth substances within plant tissues and related metabolic investigations have provided information on the mechanism of fatty acid degradation in plants. Thus, in experiments with some twenty homologous series of ω -aryloxyalkanecarboxylic acids, each series consisting of at least the first six members, it has been established by biological chromatographic and chemical methods that β -oxidation of the side chain of such acids can occur in plants. The further observation that β -oxidase enzyme systems in different plants can show substrate specificity indicated a new approach to selective toxicity, one outcome of which was the discovery of the selective herbicidal activity of certain phenoxy butyric, caproic and octanoic acids. Some of these compounds, e.g. 2-methyl-4-chlorophenoxybutyric acid (MCPB) and 2, 4-dichlorophenoxybutyric acid (2, 4-DB) are now finding widespread use in agriculture for controlling weeds in specific crops. They possess unique advantages over other weed killers in that they may be safely used on cereals in the early stages of growth and on legumes such as clovers, lucerne and peas.

The general approach to selective toxicity revealed by these investigations is now being followed within the Unit in lines of work involving other enzyme controlled reactions. In addition, studies have been made on the metabolism of a wide range of indole derivatives, some of which occur naturally in plants. One outcome of this work was the discovery of a new type of reaction (δ -oxidation) whereby nitriles can be degraded within plant tissues.

Investigations are also proceeding on the distribution of natural growth hormones and hormone inhibitors in plants at different stages of growth and the new growth-promoting substances known as gibberellins are also receiving attention.

CURRENT WORK ON FUNGICIDES

Groups of chemicals have been prepared for studies on fungicidal action and new compounds which may have commercial importance as volatile fungicides are being investigated.

In one approach to the problem of conferring fungicidal protection to plants by means of chemicals acting within the tissues, compounds have been synthesised which on structural grounds may be expected to have negligible effects on growth yet which are moved systemically in the plant. A useful basis for this work on systemic fungicides has been provided by the results of research on structure/activity relationships already referred to under growth substances. Amongst the series of compounds so far investigated, certain arylthioalkane-carboxylic acids, e.g. α -(2-chlorophenylthio) propionic acid, when applied in aqueous solution at very low concentrations (e.g. 10 parts per million) through the roots, have been shown consistently to give a highly significant degree of protection to broad bean (*Vicia faba*) seedlings against infection by *Botrytis fabae* and to tomato plants against *Alternaria solani*.

While there are many advantages in controlling plant diseases with systemic fungicides, it must be emphasised that, in experiments to date, the degree of

protection afforded by such means has proved inadequate to provide control in the field. Much further research will be required before it is known whether systemic fungicides are to find practical use in protecting crops against disease. In the meantime the knowledge that some degree of control can be achieved by chemicals acting within the plant may be regarded as encouraging. Evidence has now been obtained that such systemic activity, leading to a change in the disease resistance of the plant, can arise in various ways. The most important of these seems to be an indirect effect of the "foreign" molecule on the biochemistry (metabolism) of the host plant. This effect has been shown with some compounds to lead to increased resistance and with other compounds to increased susceptibility towards the diseases investigated.

Other studies within the Unit are concerned with the natural resistance of plants towards fungal diseases. While this property may often be associated with particular morphological characteristics in the host, evidence has been obtained that in some cases natural resistance may have a chemical basis. This has provided a second line of approach to the study of systemic fungicidal action. An antibiotic with fungistatic properties has been found to occur in the stems and roots of broad bean (*Vicia faba*) seedlings and this may well be concerned in providing protection against certain fungal pathogens. The chemical nature and properties of this substance are being investigated.

PESTS AND DISEASES

A.R.C. UNIT OF INSECT PHYSIOLOGY

Department of Zoology, Downing Street, Cambridge

Director: Professor V. B. Wigglesworth, C.B.E., M.A., M.D., B.Chir., F.R.S.

Senior Scientific Staff:

W. A. L. David, M.A., Ph.D.

J. S. Kennedy, M.Sc., Ph.D.

A. D. Lees, M.A., Ph.D.

A. Milne, M.A., D.Sc., Ph.D., F.R.S.E.

J. W. L. Beament, M.A., Ph.D.

The Unit was established in 1943. Its objective is to provide fundamental knowledge on the physiology of insects. While such knowledge may not be of immediate value in the control of insect pests, it provides basic information required by the applied entomologist in developing methods of control, whether by cultural methods or by insecticides.

The staff of the Unit which on 31st March, 1957 comprised 7 scientific and 3 experimental staff is located in three laboratories:—

- (a) The Sub-department of Entomology in the Zoology Department at Cambridge (the Director and two scientific officers). Here the work is mainly on the more fundamental aspects of insect physiology.
- (b) The Entomological Field Station at Cambridge (three scientific officers and two experimental officers). Here glasshouses and garden plots are available and research work concerns the physiology of nutrition and behaviour of aphids and the use of insecticides against insects feeding on plants.
- (c) The Department of Agriculture, King's College (University of Durham); Newcastle-upon-Tyne (two scientific officers and an experimental officer). Here the work concerns the detailed study of the ecology and physiology of selected agricultural pests with special emphasis on the factors which bring about fluctuations in their numbers.

CURRENT WORK

The physiology of growth and metamorphosis in insects. This subject has been under study for many years. The particular aspects studied during the year were the role of the circulating blood cells in growth, the course of oxygen consumption during the moulting cycle, and the remarkable cycles of formation and involution in the muscles that take place during growth.

The nutrition and behaviour of aphids. The factors concerned in host selection and host alternation by aphids are being studied. The research deals with the colonisation of different species of plant and of different parts of a given plant and with the effects of galling and of virus disease. It has been established that the nutritional value of the phloem sap of plants on which aphids feed varies greatly with the physiological state of the plant. It is high in young leaves and in senescent leaves; much less in normal mature leaves. These differences are reflected in the feeding preferences of aphids, that is, in their distribution on the plant, and in the rate of their multiplication.

The effect of the environment, notably the temperature and photoperiod, on the dormancy and development of insects. Studies on the physiology of the Fruit Tree Red Spider Mite which have now been concluded emphasized the importance of the length of day in determining whether the female will lay "diapause" eggs which will remain dormant all winter or "non-diapause" summer eggs which will develop immediately. A long-term investigation has now begun on the effects of temperature and photoperiod on the development of sexually reproducing forms of aphids.

The ecology and physiology of the Garden Chafer. A study of the biology and ecology of the Garden Chafer (*Phyllopertha horticola*) in Cumberland has been concluded. Much information has been accumulated about the life cycle of this insect, the rate of multiplication and the factors which lead to the build-up of the population to destructive levels in certain restricted localities. It has been found that the number of eggs produced by the adult (an average of no more than 14 per female) is determined solely by the nutrition of the larva and the amount of reserve substance it can store and carry over to the adult stage. It is also noteworthy that the female on emergence comes to the surface of the ground for only a few moments for mating and then burrows again to lay her eggs: the insects seen later in quantity have all completed their reproductive phase.

The action of systemic insecticides. Using various plants, the absorption, translocation and persistence of certain organophosphorus and fluorine compounds are being studied. This information is being related to the insecticidal action of these compounds on phytophagous insects, parasites and predators, and to their phytotoxic effects.

The entry of poisons into the eggs of insects. In earlier years much information had been got about the structure of the egg shell in insects with special reference to water proofing and respiration. This knowledge has now been used as a basis for studying the entry of poisons into the egg of the Cabbage Butterfly (*Pieris brassicae*).

Passage of chemicals through the insect cuticle. As a preliminary to the study of the factors that control the entry of insecticides through the integument of insects, an analysis has been made of the physico-chemical factors that determine the rate of passage of various simple chemicals through the cuticle of the locust.

A.R.C. VIRUS RESEARCH UNIT

University Farm, Huntingdon Road, Cambridge and
Molteno Institute of Biology and Parasitology, Downing Street, Cambridge

Director: K. M. Smith, C.B.E., D.Sc., Ph.D., F.R.S.

Senior Scientific Staff:

R. Markham, M.A., Ph.D., F.R.S.

J. D. Smith, M.A., Ph.D.

In 1927 a research station was founded under the auspices of the Ministry of Agriculture and attached to the School of Agriculture, University of Cambridge. The first Director was the late Dr. R. N. Salaman with the present Director as Senior Research Assistant, and the aim of the Station was the investigation of the virus diseases of the potato. Later the scope of the work was enlarged to include the virus diseases of many other important agricultural and horticultural crops.

During these early years much fundamental work had to be done since there was no other centre of plant virus research in Great Britain at that time and the available knowledge of plant viruses was extremely meagre. The different viruses and virus complexes affecting the potato plant were identified and resolved and their insect vectors and mode of spread in the field discovered. A series of tests for identifying the viruses in the potato plant was developed and used for building up nuclear stocks of virus-free seed potatoes. These methods are still largely in use and have been copied all over the world. The recognition of the part played by viruses in the potato industry has led to a greatly increased yield. During this time also many plant viruses of great scientific and economic importance were discovered such as that of tomato bushy stunt, the first plant virus to be obtained in a three-dimensional crystalline form, turnip yellow mosaic virus which has also been crystallized and which gave the first unequivocal evidence of the part played by nucleic acid in the multiplication of a plant virus; and tomato spotted wilt virus which was thus discovered for the first time in Europe in 1931. This virus was first described in Australia in 1915 and is now world-wide in its distribution.

In 1947 the Plant Virus Research Station was taken over by the Agricultural Research Council and the work expanded and developed. A new laboratory was built and the equipment necessary for the modern study of viruses was provided.

The work of the Unit now comprises the electron microscopy of plant and insect viruses both within and outside the host cells; biochemical work on the virus nucleic acids; physiological studies of virus-diseased plants; experiments on the insect vectors of plant viruses; and the examination of the growth of plant viruses by tissue culture methods. In addition the Unit assists officers of the National Agricultural Advisory Service with the diagnosis of plant virus diseases.

On 31st March, 1957 the scientific and experimental staff of the Unit numbered nine.

CURRENT WORK

During investigations of the viruses affecting insects of agricultural importance, a new virus was isolated from the leather-jacket, the larva of the crane fly or daddy-long-legs (*Tipula paludosa*). With the collaboration of Prof. Robley Williams from the Virus Laboratory, University of California, this virus was obtained in crystalline form, only the second animal virus to be crystallized, the first being that of poliomyelitis. This virus has some very remarkable optical and physical properties and because of this is of great interest to crystallographers. Other new and important viruses have been isolated from the caterpillars of the

white butterflies (*Pieris brassicae* and *P. rapae*), of the winter moth (*O. brumata*), of the pine sawfly *Neodiprion sertifer*, the pine looper *Bupalus piniarius* and the clothes moth, *Tineola bisselliella*. Arising out of these studies is the possibility of using the viruses obtained in this way for the control of agricultural or economic pests and this line of work is being pursued.

On the biological side of the plant virus work, investigations are being carried out on the distribution of viruses within certain tissues of the leaf. It is hoped from this to obtain information on the transmission of these viruses by aphids. The effects of heat on virus-infected plants are also being studied, with the practical aim of the cure of valuable plants by the elimination of the virus by this method.

The biochemists of the Unit are engaged on fundamental studies of the virus nucleic acids with special reference to the incorporation of thiouracil and 8-azuguanine into ribonucleic acids. This suggests a line of chemotherapy because certain of the chemicals which become incorporated in the virus inhibit its multiplication in the living plant. Work is also being carried out on the effect of purine and pyrimidine analogues on the multiplication of the bacterial viruses and on their effect upon the nucleic acids of bacteria.

HILL FARMING

HILL FARMING RESEARCH ORGANISATION

48, Palmerston Place, Edinburgh, 12

Director: A. R. Wannop, O.B.E., B.Sc. (AGR.), B.ENG., F.R.S.E.

ANIMAL STUDIES

Head of Department: J. F. Robinson,
B.Sc. (Agr.)

J. N. Peart, M.Sc.

BOTANY

Head of Department: R. F. Hunter,
B.Sc. (Agr.)
J. King, B.Sc., Ph.D.
I. A. Nicholson, M.Sc., B.Sc. (Agr.)

Secretary: R. S. Boyd

The Hill Farming Research Organisation was established in 1953. In the following year it became an independent grant-aided research institute with a Board of Management appointed by the Secretary of State for Scotland, after consultation with the Minister of Agriculture and Fisheries and the Agricultural Research Council. At the same time the three hill farm research stations in Scotland were transferred to it.

Its tasks are twofold:—

- (a) To promote and implement for the Agricultural Departments a co-ordinated programme of work subject to the scientific oversight of the Agricultural Research Council on the problems arising from hill farming which require further research.
- (b) To manage on behalf of the Department of Agriculture for Scotland the hill farm research stations in Scotland.

At first the headquarters staff, deliberately limited to five, were housed in three small rooms, but in the spring of 1955, large, though still temporary, premises were secured in the business area of Edinburgh.

The three hill farm research stations are Glensaugh in Kincardineshire (2,430 acres), Lephinmore in Argyll (2,800 acres) and Sourhope in Roxburghshire (2,765 acres), and with work initiated during the year the resources of

these will soon be well utilised. Laboratory facilities at the field stations are not yet satisfactory, but are being developed, and there is a need for animal houses for pilot experiments with sheep, which are necessary before certain large scale trials can be made on the hill proper.

On 31st March, 1957 the scientific and experimental staff of the Organisation numbered nineteen.

CURRENT WORK

Since 1954 the Organisation's task has been to recruit suitable scientific staff, to develop as fully as possible the resources of the three hill farm research stations and to establish co-operation with other research institutes and with Universities and Agricultural Colleges. In the latter sphere co-operative work is proceeding with the Macaulay and Rowett Institutes, the Animal Breeding Research Organisation, the Institute of Animal Genetics, the Animal Diseases Research Association and the three Scottish Colleges of Agriculture.

Department of Animal Studies. The major study that has been initiated concerns the nutritional level of ewe hoggets in their first winter and the supplementary feeding of hill ewes in winter. During the year a critical study of three planes of nutrition for hoggets was begun with Cheviots at Sourhope. Records of the effect on growth, development and subsequent breeding performance are being made, and will not be complete until the animals leave the flock at 6½ years of age. The supplementary feeding of ewes with hay or roots or concentrates initiated in the previous year at all three stations was continued, and an examination of the results and weight changes suggests new lines of approach to hill flock management.

At Glensaugh, where the dentition of the Blackface flock results in early drafting of ewes and difficulty in maintaining flock numbers, collaborative work with the Rowett Institute has been continued.

In Scotland the dominant hill breeds are the Blackface and Cheviot, within which there are two or more types, while in the North of England the Swaledale is dominant. Comparisons of four types of Blackface at Glensaugh and of two types at Sourhope, when maintained in a common environment, were continued for the sixth and fourth seasons respectively. All the female stock in the trial have now been bred on the trial farms. At Lephinmore a method of "upgrading" by the continuous use of sires of three types of Blackface and of the Swaledale breed has been initiated on a common stock of Blackface ewes. This will provide ancillary information on the possible effects of heterosis in reducing lamb losses at birth.

Progress has been made at Sourhope with a selection experiment in collaboration with the Animal Breeding Research Organisation with the object of improving the milking ability of Cheviot ewes.

The grazing management trial at Sourhope, in which a mixed stocking of cattle and sheep has been compared with a stock of sheep only, was continued and provides striking evidence of the superiority of mixed grazing on grassy hill swards. Without lime or fertilisers the output as a result of mixed stocking has been increased by 50 per cent. This must be partly attributed to fencing into enclosures, though these are large and extend to 250 acres each. On another heft at Sourhope an attempt is being made, by means of enclosures and controlled grazing, to secure an increase in the rate of stocking and of prolificacy. Herbage growth in the enclosures is reserved for use at crucial seasons.

In the west of Scotland lambing percentages tend to be low. This is partly because mating and lambing take place on extensive hill grazings, with one ewe to four or more acres. During the winter of 1956-57 at Lephinmore, the ewes

on one hirsle were mated in enclosures and lambled below a cross fence on the hill. The subsequent lamb crop has been 20 per cent. above normal.

Lephinmore was first retained for research purposes in 1949 after an afforestation plan had been agreed for the farm between the Department of Agriculture for Scotland and the Forestry Commission. Part of the planting programme was deferred until 1962 so that a comparison could be made between a hirsle more or less unplanted and one where the lower slopes are planted. This comparison has continued, but it will be many years before the full effects of the afforestation can be assessed. Meanwhile, from the point of view of using the remaining agricultural areas to the best advantage, it is clear that too large a proportion of the lower slopes has already been planted.

Other work during the year related to the pattern of the oestrus cycle in Cheviots and Blackfaces, the fattening ability of lambs of the various strains, the performance of cattle on the hill at all three stations and the provision of facilities and samples for veterinary workers to undertake studies on helminths, liver fluke and the sheep tick. A cobalt dosing trial at Sourhope indicates a cobalt deficiency on part of the station, contradicting a previous trial carried out almost ten years ago.

Department of Botany. Work has continued and been extended on the autecology of some of the more important species occurring on hill grazings. Studies continued of the competition between *Nardus stricta* and *Calluna vulgaris* following a muirburn and subsequent regeneration of the heather; the competitive relationships between *N. stricta* and different plant communities as affected by grazing and soil moisture; the nutritional requirements of *Trifolium repens* with reference to calcium, molybdenum, and phosphorus, and the evaluation of the indigenous strain of *Rhizobium*. Work has now started on a phytosociological classification of *Molinia* and on the soil moisture condition characteristic of these communities while autecological work on *C. vulgaris* has begun with studies of the ecotypic differentiation of the natural population, the regeneration of the plant after burning, and its rate of growth and recovery under different grazing regimes.

The phytosociological work which is primarily concerned with arriving at a classification of the *Agrostido-fescetum* has continued and investigation of the botanical effects of various practices in the management of hill pasture has, during the period, been considerably extended.

A long term experiment on the effect of different burning rotations on *Molinia* and heather has been laid down at three centres, and the number will be increased in future years.

Observations have continued on the effects of introducing cattle on to a pasture formerly grazed by sheep alone, and work on the botanical consequence of top dressing hill pasture with small quantities of both lime and phosphate fertilisers continued.

In September, 1956 a study on the behaviour and grazing preference of a heft of sheep was started and this will continue until September, 1958. Observations have also been made on the effect of manurial treatment on the sheep's selection of its diet. It is possible that the sheep behaviour studies will help in arriving at a decision on areas of hill to be improved, and areas which can be used for forestry without seriously reducing the stock numbers, and in deciding on the more suitable types of pasture for mixed grazing by both cattle and sheep.

From the work which has so far been done it appears that a molybdenum deficiency in the soil of the southern uplands is unlikely though it is yet too early to believe that it never occurs. It is thought, however, that most indigenous strains of White Clover, because of the inefficiency of their associated strains of

Rhizobium, may be unable to respond adequately to improved levels of fertility and so present an obstacle to the improvement of hill pastures by manurial treatment. This problem is under further study.

Initial botanical records have been taken on 36 sites where drainage schemes have been carried out, and experimental drainage work has been established at Birkhill, Lanarkshire. Using radio-active tracers, work has been done, in collaboration with the Macaulay Institute, on the rooting depths of plants growing in peat.

The drainage survey has revealed what is felt to be a lack of any rational understanding of how to use the technique of open hill draining. Naturally it is the purpose of this organisation to develop such an understanding yet it may not be out of place in this report to draw attention to the deficiencies not only in theory but also in the practice of hill draining as it is today.

OUTCOME OF RESEARCH

Hill research is essentially long term in character. Because of the topographical, climatic and vegetational variations over even a limited area of a hill, it is impossible in any animal investigation or study of pasture-animal relationships to arrange fully replicated trials. Continuation of trials under hill conditions is therefore necessary over a period of years. Further, where most of the research on animals concerns a breeding flock, the effects on the performance of the subsequent generation is of importance, and must be considered in assessing the effects of any treatment. Many ecological studies are also very long term in character. Some time must therefore elapse before the research in progress can be of practical value to hill farming and the production from hill areas.

A report on the work of the Organisation is published every three years.

ANIMAL BREEDING

A.R.C. ANIMAL BREEDING RESEARCH ORGANISATION

Headquarters: "Glenbourne", South Oswald Road, Edinburgh, 9

Director: H. P. Donald, D.Sc., Ph.D., F.R.S.E.

Consultant (Part-time): Professor R. G. White, C.B.E., M.Sc., F.R.S.E.

Senior Scientific Staff:

N. Bateman, B.Sc., Ph.D.

H. B. Carter, B.V.Sc.

J. G. Hall, Ph.D., M.R.C.V.S.

J. L. Hancock, M.V.Sc., Ph.D., M.R.C.V.S.

J. W. B. King, B.Sc., Ph.D.

J. H. Watson, B.Sc., Ph.D.

G. Wiener, B.Sc., Ph.D.

G. B. Young, Ph.D., M.R.C.V.S.

Livestock Officers:

Pigs: G. R. H. Bishop, M.Sc., N.D.A.,
N.D.D.

Sheep: J. L. Read, B.Sc.

Secretary: F. H. James

By 1945 it had become clear that effective research in Great Britain in the field of animal breeding would require considerably greater resources than had been available up to that time. The Council, therefore, decided to establish a new organisation for this research and the first steps were taken towards developing the necessary field stations and laboratories.

The aim of the organisation is to obtain knowledge which will assist stock-breeders and others consistently to produce stock which is not only superior in meat, milk, and wool production, but also in fertility and suitability for particular environments.

This aim is being pursued with the aid of six field stations acquired at various times during the past eight years in England, Wales, and Scotland. Two are devoted principally to hill sheep, two to pigs, and two to dairy cattle. A seventh is being developed for more varied studies, including climatology, wool biology, reproduction in pigs and pilot experiments with mice. The administrative headquarters in Edinburgh links these stations together and provides laboratories for genetical studies of the data coming from them.

On 31st March, 1957 the scientific and experimental staff of the Organisation numbered fifty-one.

CURRENT WORK

Dairy Cattle. The current work falls into two categories, crossbreeding and twin studies.

Organised crossbreeding, which is applied by many farmers to sheep and pigs, has not hitherto been used on any considerable scale in dairy cattle breeding. With the advent of Artificial Insemination it has become a practical possibility but there is little information about the relative merits of purebred and crossbred cows. A trial has therefore been started on the Organisation's Staffordshire farm for the purpose of obtaining some evidence on the question. Bulls standing at Milk Marketing Board A.I. centres are used to produce both pure and crossbred progeny from Friesian, Ayrshire and Jersey cows. Whatever the results, they will have been obtained by the use of bulls which are available to breeders through A.I. It has always been an objection to crossbreeding dairy cattle that their reproductive rate is insufficient to sustain a large crossbred population without breeding from the crossbreds themselves and so it has been an integral part of this experiment to make 3-breed crosses from the 2-breed first crosses with a view to determining whether a self-supporting cross-bred herd is economically advantageous. Since a generation of cows lasts at least 4-5 years it takes some time to carry out such an experiment as this and sufficient data will not be obtained from it for some years yet.

Twin studies became possible when it was discovered that identical as well as fraternal twins occurred in cattle with a frequency that made it practicable to use them for research purposes. So far some 330 pairs of identical twins have been purchased from farmers and of these 130 pairs have been made available to other research institutes. With a pair of identical twins it is possible to give one an experimental treatment and to use the other as a control uncomplicated by hereditary differences. Some work of this kind aimed at studying the efficiency of food use by growing cattle has been started. The main effort with twins has, however, been directed to discovering why they behave so much more alike than estimates of the importance of heredity would lead one to expect. There seems to be more to this resemblance than mere identity of inheritance. If the cause of this can be made clear, the way may be opened to improving the precision with which the genetic merit of breeding stock may be judged.

One of the most fruitful ways in which twins have been used lies in the field of blood grouping. A comparison is being made of the antibodies found in twins before and after deliberately mismatched blood transfusions. This study promises to disclose the relative importance of genetic and environmental factors in this aspect of immunity. At the same time new blood groups are being found and their mode of inheritance investigated. This work is providing the scientific basis which a parentage-testing and freemartin diagnosis service must necessarily have.

Sheep. After a survey of hill sheep farming had disclosed that breeders disagreed about the changes that would constitute an improvement, it became clear that what was needed was some fundamental information on the nature of adaptation to hill conditions and about the way in which sheep respond to attempts to alter their wool, their size, and their conformation. This is the task the Organisation has set itself in the hope of being able to advise breeders just what modifications brought about by selecting their breeding stock could increase the productivity of their flocks. A simple illustration of this approach is provided by the Organisation's flock of Welsh Mountain sheep in Wales. Many breeders contend that the essential quality of hardiness in these sheep is dependent on a large proportion of kemp in the adult fleece. This belief is partly based on the fact that there is a close association between kemp in the adult fleece and strong hairy birthcoats in the newly-born lambs. Such covering is regarded as advantageous to survival by protecting them in cold wet weather. There is, however, no evidence to show whether it is the hairiness or some other attribute of wool on a lamb which is important. As the type of birthcoat certainly affects quality if not also weight of fleece grown later, the question is far from academic. An attempt is therefore being made to breed from the same original stock two sub-flocks, one with hairy and the other with smooth birthcoats, so that they may be compared in other respects. All the sheep are pedigreed in the sense that both sire and dam are known; and all are subject to observation of fertility, growth and wool production under typical Welsh hill conditions. It will in this way be possible to estimate the part played by heredity in determining the performance of these sheep and what kinds of selection, particularly of rams, can be expected to lead in the desired direction.

The work of the Organisation on its Blackface flock in Scotland is of the same basic character. Here, however, the selection of breeding stock follows somewhat different lines. Sub-flocks varying in length of leg and hairiness of fleece are being compared with sub-flocks in which natural selection is being given as much scope as possible. These latter sub-flocks are intended to show what kind of sheep are produced if artificial selection is suspended and therefore the extent to which breeders have to contend (perhaps unnecessarily) with the ill-effects of opposing the naturally best-adapted type of sheep. From this work also should come practical information about the efficacy of sire selection for various characters of economic importance.

To sheep running under hard hill conditions and producing as these do a lamb crop of only 70-80 per cent. of the ewes mated, survival at all ages is a continuous struggle and the part played by the fleece and its constituents would seem to be highly significant. A laboratory is therefore being developed to evaluate fleece characters for genetic purposes in the breeding flocks, and to permit some major features of the climate to be reproduced for studying the different types of fleece under the prevailing cold and wet conditions. In time it should be possible to say what kind of fleece a sheep needs to serve its purpose best; how most efficiently to select breeding stock to this end; and how far it is possible to compromise on fleece characters of economic importance to the wool industry. These investigations are, moreover, fundamental to the breeding of sheep anywhere and for all purposes.

Pigs. The exploitation of hybrid vigour in maize and poultry breeding is well known. In the United States the idea has been extended to pigs and it has seemed important to discover whether our British pigs can be usefully subjected to the same breeding processes. Inbred lines (132) have accordingly been founded on a wide and representative sampling of pedigree Large Whites. As expected many of the lines (109) have had to be discarded for poor performance at some stage during the three generations of close breeding that are imposed on them.

Only to a slight extent (8 lines) has their failure been due to inherited or congenital defects. Poor fertility, viability, and milk production are the principal results of inbreeding. The surviving lines, although comparing unfavourably with ordinary outbred pigs, should, by analogy with maize and poultry, include some which, when crossed, produce pigs of superior performance. Some of these lines have now reached the stage of being tested in combination and it is clear that there is an immediate improvement in productivity. Whether this improvement is sufficient to enable the line-cross pigs to perform better than the control outbred pigs is a question for the immediate future. Owing to the need to test a large number of inbred lines, such a breeding programme as this can hardly be undertaken by private individuals. If in the outcome the results are only fractionally as good as those obtained with maize, the public investment in finding successful lines will have been worthwhile.

Advantage is also being taken of the Organisation's large pig herd to obtain material for the study of the intimate details of fertilisation and implantation of eggs. Apart from its value in determining the most effective management and fertility tests for breeding stock, this work has much potential importance for the development of A.I. in pigs. Much more needs to be known before this technique can play its part in exploiting the knowledge to be gained from the country's pig testing scheme.

Mice. Although it is necessary to be very cautious in making inferences from mice to large animals, there can be little doubt that these small mammals offer a quick and relatively cheap method of trying out new ideas that are insufficiently developed to be applied immediately to livestock. The Organisation, therefore, maintains a mouse laboratory which concerns itself at present with a problem which is particularly acute in pig breeding, the discovery of an effective method of selecting breeding stock so as to improve litter size and weight.

OUTCOME OF RESEARCH

In general the research programme of the Organisation is the result of an effort to achieve, within the resources available, a reasonable compromise between conflicting demands. Solutions to some problems will be of direct value to breeders and to the livestock industry. Solutions to other problems will contribute to the fundamental knowledge of biological processes which will be the basis of future progress. In both cases it is necessary to resist the temptation to work with too few animals. The fact that livestock are expensive and slow to reproduce must be accepted if the demand for reliable and reproducible results is to be met.

A.R.C. UNIT OF REPRODUCTIVE PHYSIOLOGY AND BIOCHEMISTRY

Molteno Institute of Biology and Parasitology, Downing Street,
Cambridge

Director: T. R. R. Mann, M.D., Sc.D., Ph.D., F.R.S.

Deputy Directors:

L. E. A. Rowson, O.B.E., M.R.C.V.S.
(Part-time)

A. Walton, B.Sc., Ph.D.

Senior Scientific Staff:

C. E. Adams, B.Sc., Ph.D.

J. C. Bournsnel, B.Sc., Ph.D., F.R.I.C.,
A.R.C.S.

E. F. Hartree, M.A., B.Sc., Ph.D.

E. J. C. Polge, B.Sc. (Agric.), Ph.D.

The Unit of Reproductive Physiology and Biochemistry was established by the Agricultural Research Council, in agreement with the University of Cambridge, on February 1st, 1955. Dr. Mann, is also University Reader in Physiology of Animal Reproduction, in the Department of Veterinary Clinical Medicine, and

Mr. Rowson is Director of the Artificial Insemination Centre of the Cambridge and District Cattle Breeders, Ltd.

On 31st March, 1957 the scientific staff and experimental staff of the unit numbered eight.

CURRENT WORK

A major event of the year, in the activities of the Unit, has been the 3rd International Congress on Animal Reproduction, which was held in Cambridge, on June 25th-30th, 1956.

Physiology and biochemistry of mammalian semen and the male reproductive tract. Studies on the occurrence of ergothioneine and inositol as major constituents of semen were extended to several more species; the secretion of both these substances was shown to take place in the male accessory glands under the influence of the male sex hormone. The high content of organically-bound phosphorus in seminal plasma has been found to be derived from two substances, phosphorylcholine and glyceryl-phosphorylcholine; the latter compound was isolated from ram semen in a chemically pure form. An investigation of enzymes present in semen has revealed the presence of two very active glycosidases, namely, α -mannosidase and β -N-acetylglucosaminidase, in the epididymal secretion of the bull, boar and stallion.

Experiments on the metabolism of spermatozoa have established that in addition to fructose and certain organic acids, two other substances, namely glycerol and sorbitol, are capable of providing oxidisable substrates for spermatozoa. Experiments done with the "semen perfusion apparatus" which was designed to keep spermatozoa alive for periods of several days at 30° C, have shown that sperm motility in semen can be maintained at the highest level when fructose is present in the perfusion fluid and oxygen supplied at the same time.

Physiology and biochemistry of the mammalian ovum, foetus and the female reproductive tract. Research in this field continued to expand in several directions. Use was made of the ovum transplantation technique for the purpose of studying various factors which influence fertility in the female rabbit. Another line, concerned with the chemical composition of the embryo at the blastocyst stage, led to the discovery that at the pre-implantation stage the embryo contains a remarkably high concentration of certain growth factors and vitamins, notably vitamin B₁₂ and nicotinic acid. Further progress has been achieved in the study of hormone-enzyme relationships characteristic of the female reproductive tract. A new, rapid and quantitative enzyme test has been developed which is suitable for screening of the potency of progesterone and related steroids; this is based on the observation that the progestational response of the rabbit uterus is closely correlated with the activity of carbonic anhydrase in the endometrium. Another development of much practical value, has been the elaboration of an improved procedure for the chemical determination of progesterone in peripheral blood and placental tissue of domestic animals. In the course of this investigation, a second progestationally-active steroid was detected in the mare placenta, and was identified as 20-hydroxyprogren-4en-3one.

Artificial insemination, with special reference to breeding of pigs. More efficient preservation of bull semen was achieved by further developments in the glycerol-freezing technique and in the use of artificial semen-diluents. The experience gained with bull semen has helped to develop methods of semen storage and artificial insemination in other animal species, particularly the pig.

Studies on the relationship between reproduction and nutrition. Experiments which were carried out on several pairs of identical (monozygous) bull-calves

indicate that underfeeding of maturing bulls produces a marked delay in the onset of male sex hormone activity, as reflected in the retarded secretory activity of the male accessory organs. Moreover, the restricted food intake also causes a lag in the onset of spermatogenic function. However, the delay in the appearance of sperm (in electrically-induced ejaculates) is much less pronounced than that in the secretory function of accessory glands.

ANIMAL DISEASES

A.R.C. FIELD STATION

Compton, Newbury, Berks.

Director: W. S. Gordon, C.B.E., PH.D., M.R.C.V.S., F.R.S.E.

BACTERIOLOGY

Head of Department: S. J. Edwards,
D.SC., M.SC., F.R.C.V.S.
A. McDiarmid, D.SC., PH.D., M.R.C.V.S.
J. D. Rankin, M.R.C.V.S.

PATHOLOGY

Head of Department: H. H. Holman,
D.SC., PH.D., M.R.C.V.S.
I. H. Pattison, B.SC., M.R.C.V.S.

ANIMAL BEHAVIOUR AND ANIMAL HUSBANDRY

Head of Department: A. Brownlee,
B.SC., M.R.C.V.S.

APPLIED GENETICS

Rachel Nussbaum, ing. Agric. (Vienna)

RADIOBIOLOGICAL LABORATORY

Hon. Deputy Director: R. Scott Russell,
M.A., M.SC., PH.D.

Hon. Consultant: J. F. Loutit,
D.M., M.R.C.P.

Plant Physiologist: L. J. Middleton, PH.D.

FARMS

Manager: E. V. Knight, B.SC., N.D.A.

ISOLATION COMPOUND

Manager: J. Elliot, M.A.

Secretary: F. R. Meakins

The Field Station at Compton, the first research centre to be established under the direct control of the Council, was set up in 1938 primarily for the purpose of intensifying research into diseases of animals (the cost of which to the country has been estimated at no less than £80 millions a year).

In such investigations, the factor of prime importance is the experimental animal itself. If the animals are faulty or die of inter-current infections, the work has to be repeated, or if the animal house accommodation is inadequate, the work has to be postponed. The aim therefore in developing the Station has been both to breed a good supply of various species of farm animals of known health history, and reared in an environment as free from disease as possible; and to provide ample accommodation to house the experimental animals in strict isolation. In these respects the Station now provides facilities on a scale which is unmatched elsewhere.

The Station now occupies 2,000 acres of land at Compton. It is typical Berkshire Downland of low inherent fertility on which are maintained a fluctuating number of animals according to the experiments in progress. At present there are approximately 1,100 dairy cattle, 2,500 sheep, 1,200 pigs, 330 goats, 2,000 head of poultry and 20,000 small animals. The Station has a central laboratory, 3 dairy farms producing normal animals and milk, a pig farm, a poultry farm and a sheep flock. Originally, six isolation buildings, each to accommodate 10 adult cattle, were provided but since 1950 there has been built an isolation compound with 22 buildings, each to take 24 adult cattle, together with a central postmortem room and laboratory. The buildings have been so designed as to accommodate in isolation either 588 adult cattle or much larger numbers of young cattle, sheep, goats, pigs, ponies or poultry.

On 31st March, 1957, the scientific and experimental staff of the Station numbered twenty-five.

CURRENT WORK

Apart from numerous *ad hoc* experiments undertaken on behalf of the Council itself or for scientists at other research stations who require extension of their work to farm animals, the main diseases under investigation are bovine abortion, mastitis, Johne's disease, scrapie disease of sheep and pneumonic disease of pigs. Much work has also been done on the growth promoting effect of antibiotic supplements in the diet of young animals, special attention being given to mode of action. A considerable amount of work has been done on bloat in cattle and grass sickness in horses. A study has recently been completed on the effect of thyroxine on wool yield in twelve different breeds of sheep. An experiment involving 100 calves to assess the immunising value of a vaccine for the prevention of parasitic pneumonia in collaboration with Glasgow University Veterinary School was recently completed. An experiment is in progress involving 100 cows to compare the effects of feeding high and low protein concentrate mixtures at two different levels during the last 6 weeks of pregnancy upon the subsequent productivity in collaboration with the National Institute for Research in Dairying. An experiment involving 72 cows to compare groundnut meal and herring meal as concentrate feed for milk production in collaboration with The Rowett Research Institute is also in progress.

Contagious Bovine Abortion (Brucellosis). A method of assessing the immunising value of vaccines against *Brucella abortus* using guinea pigs was developed between 1932 and 1936, by members of the Compton staff while at Moredun Institute, Edinburgh. This work was undertaken in small animals with the intention, if successful, of extending it to cattle at a later date. The method was adopted and perfected by other research centres and extension on a large scale to cattle kept in isolation became possible with the establishment of the Field Station at Compton in 1938. Hundreds of cattle have now been used in experiments which have compared the immunising value of certain dead vaccines and also of living vaccines prepared from two strains of reduced virulence, namely, strain 45/20 (McEwen) and the American strain 19.

Briefly, the principle adopted in assessing the immunising value of a vaccine consists in inoculating it into suitable cattle and, mid-way through pregnancy, exposing the vaccinates along with equal numbers of controls, to a standard challenging infection. The degree of infection in the two groups is then compared. By this means, evidence was obtained to indicate that strain 19 produced a better immunity in cattle than 45/20 and this confirmed earlier experiments in guinea pigs. Further, the character of reduced virulence of strain 19 appeared to be more stable than that of 45/20 because, when passaged in series through pregnant cattle for seven generations, strain 19 retained its avirulent characters, whereas strain 45/20 became fully virulent.

On the evidence of the experiments carried out at Compton, the Ministry of Health agreed to permit the use of a living vaccine, prepared from strain 19, for nation-wide use and the Ministry of Agriculture undertook the production of this vaccine.

Evidence had still to be obtained on the duration of immunity following one or more vaccinations and, to determine this an experiment, involving 534 cattle, was started in 1949 and completed in 1956. Briefly, the result showed that three vaccinations were slightly better than two, two slightly better than one at 18 months, and one at 18 months slightly better than one at 6 months. There was however no significant fall in immunity between the first and fifth pregnancies with any of the methods of vaccination and, in view of the vast increase in cost of multiple vaccination, the persistence of agglutinins in the blood

following adult vaccination and the fact that vaccination at 6 months of age gave a serviceable immunity at the fifth pregnancy, it was decided that this should be the method of choice for control of the disease in the field. Nevertheless, the ideal vaccine would be one prepared from dead organisms of a strain which does not produce agglutinins in the blood. Such a vaccine has now been made from strain 45/20 to which an adjuvant has been added and when tested in guinea pigs it has given a level of protection which equals that produced by a living vaccine. This work has now been extended to cattle and is actively in progress.

A study of the pathology of Placentitis in cows affected with Brucellosis and the susceptibility of the female genital tract to infection in various physiological states is in progress.

Abortion due to Vibrio foetus (Vibriosis). During an investigation of apparent "breakdowns" in immunity to Brucellosis in the field, a number of strains of *Vibrio foetus* were isolated and their *in vitro* characters studied. The effect of these strains on pregnant rats is being examined prior to a possible extension of the work to cattle and sheep. Studies are also in progress on the pathology and immunology of the disease produced in rats by the infective agent of enzootic abortion in sheep.

Mastitis in cows. Work on this disease continues along two main lines. The first is a systematic study of the bacteriology and epidemiology of the disease, concurrently with a study of milking methods and the use of chemo-therapeutic agents and antibiotics for its control. The second is a comprehensive study of the pathogenesis of the disease and its pathology from the earliest to the latest phase of infection with the various organisms responsible for the condition. Coupled with this are immunological studies to determine if a serviceable degree of immunity to any of the causative organisms can be produced.

In the treatment of the disease many therapeutic agents were tested and of these the best was a sulphanilamide cream which was highly successful with the streptococcal forms of mastitis. This was superseded by penicillin which is less irritant, and it is of interest to record that the first two cows ever to receive penicillin by intramammary infusion were treated at Compton in 1943, with penicillin recovered from the urine of some of the early human patients to be treated under the care of Sir Howard Florey. These two cows were cured, but several years elapsed before a sufficient supply of penicillin became available to confirm that this was not a chance result. When supplies became available, *Str. agalactiae*, the prevailing infection in the Compton herds, was eliminated and thereafter the method of whole herd treatment was extended to field trial on other farms with similar results.

Another interesting aspect of this work was the discovery that some mastitis infected cows, purchased for experimental treatment, were found to have primary tuberculosis of the udder resulting from the introduction of contaminated teat syphons into the teat canal. It was soon learned that teat syphons contaminated with milk and tubercle bacilli required very perfect sterilisation which, under field conditions, was not always easy. To eliminate the need for this, much thought was given to the development of a single dose container which would also act as the injection apparatus. This resulted in the adoption of a collapsible metal tube with a nozzle in the form of a teat syphon over which a screw-on cap was fitted. These tubes hold one dose of the therapeutic substance to be applied; they also act as the injection apparatus and have the advantage that after the dose has been injected they are discarded. This eliminates the risk of carrying infections from one cow to another during treatment of a series of animals. Tubes of this type have been adopted for general use in the treatment of mastitis throughout the world.

Since the elimination of *Str. agalactiae* from the three dairy herds at Compton eleven years ago the once prevailing type of clinical mastitis has disappeared. Nevertheless, a high incidence of staphylococcal organisms (about 60–70 per cent) in the milk and a lesser incidence (10 per cent) of *Str. dysgalactiae* and *Str. uberis* occurs. In spite of these high milk carrier rates, clinical mastitis develops in only about 1 of every 10 carrier cows per annum and these generally respond to antibiotics, possibly because treatment is applied at the first sign of clinical disease.

The serum of cows in the Compton herds contains staphylococcal antibodies which tend to increase in quantity with the age of the cow. This is probably due to the presence of staphylococci within the udder, because the antitoxin is specific for the type of staphylococcus present in the milk.

During the last three years work has been in progress to assess the value of prophylactic injection with penicillin via the teat against *C. pyogenes* infection in the dry cow (Summer Mastitis). Though the incidence of the disease has been low in untreated controls, no cases of summer mastitis have occurred in the treated animals.

Johne's Disease. Johne's Disease is the cause of considerable losses in cattle. It is difficult to assess whether or not the overall incidence of the clinical disease throughout the country is rising. On individual farms the picture varies; on some the disease is on the increase, while on others it is on the wane. One thing that has become clear is the fact that cattle can live their useful lives producing beef or milk and when finally killed for human consumption they may be found to be harbouring the bacillus of Johne's disease in lymph glands of the intestine. Extensive surveys of hundreds of cattle passing through various abattoirs have shown that as many as 15 per cent of the normal cattle may harbour this organism without apparent ill-effect. This suggests a more widespread distribution of the organism than was hitherto believed, that it is not a highly pathogenic organism in its own right, and that some unknown aggravating factor causes it to produce the clinical disease in certain animals that harbour the infection. Work on the comparative susceptibility of young and old animals has shown that while young calves can be infected with regularity mature animals receiving the same test dose appear to resist infection.

As a result of this observation attention has been directed towards the study of the disease in cattle infected with the causal organism before they have reached 5 weeks of age. These experiments have to be of long duration as the disease may not appear until 3 or 4 years after infection.

Experiments designed to establish a series of known repeatable infective doses of the organism when given by the intravenous route were completed this year. Doses which can be used in further experiments on trigger mechanisms and for testing the efficiency of vaccines, sera and therapeutic agents, have been calculated. During these experiments the opportunity was taken to study the course of the disease in cattle with particular reference to the excretion of the organism in the faeces, the development of skin sensitivity, and the production of detectable circulating antibodies. Attention is also being given to establishing methods of producing the disease by the oral route.

Methods of diagnosis have been investigated, especially diagnosis by means of a complement fixation test. All the cows under experiment in the Isolation Compound, and the majority of the cattle on the three farms on the Station, have been used for this purpose.

Studies are in progress on the immunity mechanism in Johne's disease, especially relating to the apparent resistance of the mature animal. During the course of these studies the disease, in its clinical form, has been set up in the rabbit, which has not hitherto been recorded.

A method by which antibiotics or chemotherapeutic agents may be preliminarily screened in mice for efficiency in treatment or prevention is being sought.

As the general investigation progresses, it is intended to begin controlled experiments to test the efficiency of vaccines in the prevention of the disease in cattle.

Scrapie Disease of Sheep. Scrapie is a neurosis of sheep characterised by an intense pruritis and locomotor disorder. It has been known in European countries for over 200 years and while it may occur in almost any part of Britain the incidence is rarely ever high. The occurrence of the disease in Australia, New Zealand, Canada, and United States, in sheep exported from Britain, has caused these countries to place a ban on the further importation of British sheep. In U.S.A. the disease has been made notifiable and a slaughter policy is in progress.

Between 1935 and 1942 a number of the Compton staff, while working at Moredun Institute, succeeded in transmitting this disease by inoculation of brain tissue from affected into normal sheep. Evidence of the possible spread of the disease by co-habitation between affected and healthy animals was also obtained. A peculiar feature of the disease is the long incubation period (4 to 18 months) and the low and variable rate of infection (at best about 60 per cent) in inoculated sheep. The transmissible agent has been passed in series for many generations through sheep by means of cell free filtrates and in this respect it resembles a filtrable virus. Its remarkable resistance to heat and chemical sterilizing agents, however, make it difficult to accept as a living virus. At Compton the disease has been successfully transmitted from sheep to goats and back to sheep again. A feature of distinct interest is the fact that of 67 goats inoculated every one has developed the disease with incubation periods ranging from 7 to 22 months. If this 100 per cent "take" in goats continues to hold good it will be most helpful to the general investigation of the disease. At present 24 different breeds of sheep are being maintained indoors to study their comparative susceptibility to the disease, and much work on the histo-pathology and many other aspects of the disease is in progress.

Antibiotics in Diets. Work on pigs, calves and thoroughbred foals has confirmed that supplementation of the diet with penicillin or aureomycin increases growth rate and improves food conversion in young rapidly growing animals. The response varies with the environment, being greatest usually in heavily contaminated surroundings and less spectacular under conditions of good hygiene. Much work has been done to trace the distribution of the antibiotic in the body tissues following different levels of feeding with a view to throwing more light on the mode of action. Present indications suggest that at levels between 16 and 32 parts per million of antibiotic in the diet detectable blood levels are maintained, which suggests that the antibiotic may be exerting a prophylactic effect on some of the debilitating conditions of young animals. If this proves to be true it may have far-reaching effects in the control of disease in young animals. Experiments are in progress to measure the fluctuations in sensitivity of certain faecal bacteria to antibiotics, and present evidence indicates that changes from sensitive to resistant strains and *vice versa* occur both in animals which are receiving antibiotics and also in those which are not.

Pneumonia in Pigs. Studies already carried out have emphasised the complexity of the pneumonia syndrome in pigs. More than one etiological agent is frequently involved, and an effort is being made to establish the nature of the disease associated with each of these alone, and of each in conjunction with the others. Groups of pigs are being experimentally infected with each agent, and then individuals in the group are slaughtered for examination at different intervals after infection. In this manner the progress of the disease is being traced

through all its stages. So far the method has been applied to "virus" pneumonia, lungworm pneumonia, and pneumonia associated with a *Haemophilus*-like organism. In addition to supplying fundamental information on the pneumonia syndrome itself, this study is providing a method for the accurate assessment of prophylactic and therapeutic measures.

Polled Ayrshire Breeding Experiment. A long-term breeding project aimed at the gradual elimination of horns in the Field Station's Ayrshire cattle begun in 1947 has been proceeding simultaneously along two lines:—

- (a) Starting with about half the number of F_1 daughters of a Red Poll sire on 160 foundation dams from the Field Station's two Ayrshire herds, all the polled females and selected polled males in each succeeding generation have been crossed back to Pedigree Ayrshires. This process is being continued until a sufficiently high percentage of Ayrshire "blood" is obtained to make females eligible for Appendix B of the Ayrshire Herdbook. It is hoped that this stage will be reached with the fourth backcross by 1960; the heterozygous polled animals of this generation with approximately 97 per cent Ayrshire genes will then be mated together to produce some homozygous polled offspring.
- (b) Concurrently with the backcrosses, F_2 and F_3 generations have been produced. The main purpose of this line of breeding is the study of the inheritance and development of scurs in view of their value for diagnosing heterozygous polled individuals of both sexes. While it now appears reasonably certain, on the evidence of large numbers of test-matings, that scurred males are always heterozygous for horns, it is not yet safe to assume that clean polled males are invariably homozygous. In females where the scurs are not easily detected the situation is more difficult and requires further investigation. The crossbred generations are also being used for uncovering lethals and other inherited defects by test-mating males with their daughters.

Blood-Grouping in Cattle. This was started in August 1956 with blood grouping reagents developed by Dr. J. G. Hall at the Animal Breeding Research Organisation, Edinburgh. A number of families from the Red Poll-Ayrshire crossbred herd have been typed to date. Future efforts will be directed towards finding linkage between genes controlling blood group factors and those determining characters with a relatively simple mode of inheritance, particularly horns and coat colour.

Haematology. Advantage has been taken of the large animal population at Compton to study the physical properties of the blood and lay down some clinical standards for the calf, the cow, the kid and the goat.

Disease in Wild Life. As opportunity arises a search is made in wild mammals and birds for infective agents that may cause disease in domestic animals and man. Infections with acid fast organisms and pseudotuberculosis have been found in a variety of wild birds and mammals. Haplosporangiosis has been detected in moles for the first time in Europe. In collaboration with the Virus Reference Laboratory, Public Health Laboratory Service, a survey is in progress of the occurrence of antibodies in wild mammals and birds, particularly those associated with encephalitis, ornithosis, toxoplasmosis and Q fever.

Radiobiology. In 1956 a new laboratory adjoining the main isolation compound was occupied and work began on a study of the hazards to agriculture that might result from the contamination of soils, plants and animals with mixed fission products. In the first instance attention has been focussed on the movement of radio-active iodine and strontium in soils, plants and animals, and the preliminary results have been published. Owing to the rapid growth in

the volume of this work and its many ramifications it has been found necessary to increase the staff and laboratory accommodation and the Council has decided to transfer the work on soils and plants to a new radiobiological laboratory to be built elsewhere, and to devote the existing laboratory at Compton entirely to work on animals.

Animal Ecology. A general study of the behaviour of domestic cattle has been in progress over a period of years, and the results published. Attention has also been given to the free choice selection by cattle of a range of salts of the minerals found in animal tissues. There was a considerable individual variation in the selection made, but of the salts offered the majority of animals showed a preference for sodium chloride, dibasic sodium phosphate and 10 per cent copper sulphate in kaolin. A proportion of the animals also took calcium lactate and in some cases calves selected magnesium oxide. The other minerals were almost entirely ignored.

A study is in progress of the influence of the type of diet and the manner of feeding on the development of the gastro-intestinal tract in cattle, supplemented by similar work on the laboratory rat. In calves at 13 weeks of age, development of rumen papillae was found to be least in those fed on milk only and progressively greater in those fed on milk and hay; milk and grass; milk and concentrates. In older cattle those fed on kale and mangolds plus concentrates showed greater papillary development than those fed on hay plus concentrates and from such studies the indications are that roughage is not a factor in stimulating papillary development but that the stimulus may be related to the amount of nutrient to be absorbed from the rumen. This work has been published and is of interest especially in relation to the practice of "early-weaning" which does induce early papillary development.

FOOT-AND-MOUTH DISEASE RESEARCH INSTITUTE (Animal Virus Diseases)

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In 1924 the Ministry of Agriculture and Fisheries set up a Foot-and-Mouth Disease Research Committee and acquired for the investigation of the disease a Station at Pirbright, formerly used for tuberculin testing of cattle. The Station was modified for its new task and in 1940 a long term research programme was started. In 1951 the Committee was reconstituted as the Governing Body

of the "Foot-and-Mouth Disease Research Institute". The Council in that year became responsible for supervision of the Institute's research programme and in 1956 for administration of its grant.

An extensive building and development scheme has been in progress during the last five years. The main items have been the construction of new laboratories and three additional isolation units, each one entirely self-contained for experiments on large animals; the adaptation of units in a separate area for holding large animals for long term immunity tests; the provision of a large unit with separate sections for work on small laboratory animals, a laundry and a central boiler house, and a sewage sterilisation and disposal scheme. In addition there is now a vaccine production unit which has been installed to enable the Institute to gain experience in large scale work and so designed that modifications in the methods of vaccine production, or indeed completely new and improved methods may be introduced. There is also a new breeding unit for small laboratory animals, which works on a mass production system. A selective breeding system is maintained by detailed recording and there is a steady output of the healthy stock needed by the laboratories which is of the order of 250,000 unweaned mice and 30,000 guinea-pigs a year.

The Institute carries out research on foot-and-mouth disease and the virus which causes it, with a view to improving methods of control and eradication in Britain and overseas. Research is also carried out on certain other virus diseases which are clinically similar to foot-and-mouth disease, e.g. vesicular stomatitis and vesicular exanthema.

When the objects of the Institute were more clearly defined in 1951, it was agreed that there would be considerable advantages in the simultaneous study of a number of viruses. Lines of approach to some of the problems arising in the course of research on foot-and-mouth disease and related vesicular diseases might emerge from studies on other viruses; similarly lines of approach to diseases due to other viruses might be suggested by work on foot-and-mouth disease. The terms of reference, therefore, provide also for research on other viruses. Owing to pressure of work on foot-and-mouth and related diseases and preoccupation with the building and development during the last five years, it has not been possible so far to undertake any experiments with other viruses on any considerable scale. Consideration is, however, now being given to an extension of the activities of the Institute in this way.

On 31st March, 1957 the scientific and experimental staff of the Institute numbered twenty-seven.

CURRENT WORK

Epidemiological Surveys and Immunological Typing of Virus Strains. Prompt reporting of suspected outbreaks of foot-and-mouth disease is important in any system of control. Rapid confirmation of diagnosis and determination of the immunological type of the virus is equally important. Indeed knowledge of the type is vital if, as in areas where the disease is endemic, vaccination is involved.

Since 1948 the Institute has been carrying out the examination of suspected material sent in sealed containers from outbreaks not only in this country and the Commonwealth countries but from all over the world. It has been responsible for introducing many methods and techniques to speed up diagnosis and type determination. It is now sometimes possible to get a positive answer from a complement fixation test in a few hours. A negative answer from this test does not, however, exclude foot-and-mouth disease, since some samples may have been collected too late in the infection, and passage in animals has then to be made. Until 1950 cattle rather than guinea-pigs were used to get quick results. Experiments at Pirbright then showed that baby mice could be regularly infected

with virus and since then mice have been used extensively for this work. This has led to economy in the use and housing of cattle and to the possibility of carrying out extensive epidemiological surveys which otherwise would have been impossible. A combination of mouse passages and complement fixation tests has led to a greater number of positive results. Recently another supplementary method has been introduced. The material under examination is seeded into cultures of tissue in cups on a perspex plate. The virus will multiply in these and give virus in higher concentration for subsequent complement fixation tests and this leads to a greater chance of success. The agar diffusion technique has been applied with success also to the determination of type.

Previously only three types, O, A and C, had been recognised. These surveys have brought to light three other types in Africa, designated S.A.T.1, S.A.T.2 and S.A.T.3, and since 1955 a further type in five Asian countries designated ASIA 1. This work is continuing and is now realised to be of such international importance, in assessing the risks attached to world trade in animals, animal products and animal feeding stuffs and in relation to control measures involving regional vaccination in endemic areas, that official recognition of the Pirbright Institute as a World Reference Centre for foot-and-mouth disease is under consideration.

Genetic and Antigenic Analysis. There are thus now seven known immunological types of the virus of foot-and-mouth disease and there may be more, and within the known types it has been shown that there are sub-types. For comparison, three types of virus are known in poliomyelitis, two in vesicular stomatitis and three in equine encephalomyelitis. Since the virus of foot-and-mouth disease exhibits this multiplicity of types and sub-types as well as variability in many other properties, such as virulence for particular host species, spreading power and invasiveness, work is being done on the genetic analysis of the various factors affecting host-virus relationship. At the same time, studies are being made of possible methods of inducing mutants or variant strains in the laboratory. The methods employed include the irradiation of pure lines of virus strains isolated by the use of monolayer tissue cultures. The necessity of making parallel studies of variation in the susceptibility of the host or host-cell is appreciated; and already the results of the comparison of susceptibility of two strains of mice to infection with the virus has demonstrated the influence of the host.

The value of the gel-diffusion technique for identifying the strain of the virus, the number of antigens in virus preparations and the antibodies in serum from animals recovered from the disease has been demonstrated. It has been shown, with the seven immunological types of foot-and-mouth disease and the two types of vesicular stomatitis, that the precipitin lines are specific to the disease and to the type of virus. Immuno-electrophoresis is also being applied to these investigations.

In the biophysical department, analysis is continuing of the structure of the virus of foot-and-mouth disease and the complex response it stimulates in the infected animal. Two components of the virus with different biological activity having been separated by centrifugal analysis (one about 20 m μ in diameter and the other about 8 m μ). The electron microscope has now made it possible to study the structure of the virus particles and the treatments which lead to their disintegration.

Tissue Culture. The applied aspect of the work on tissue culture concerns the culture of virus on a scale suitable for vaccine production. At a more fundamental level, studies are being made of the relationship between the virus and the infected cell and of the growth of the virus in different tissues. These studies lead to more effective use of culture methods for vaccine production.

Three years ago the Institute reported a new method for cultivation of the virus of foot-and-mouth disease. Dispersed cells obtained by digestion of kidneys from cattle and pigs are grown in suitable media to form a cell sheet on glass. These cell sheets covered by an agar gel are similar to the cell sheets of monkey kidney used for the growth of the virus of poliomyelitis. They provide a method for accurate determination of the amount of virus (virus titration), for each infectious unit seeded on to the sheet sets up an area of cell degeneration or 'plaque'. Pure lines of virus may be isolated by repeated selection of single plaques in several transmissions on cell monolayers.

Pathology and Experimental Cytology. The easily recognised clinical signs of foot-and-mouth disease are vesicular lesions on the mouth, especially the tongue, and the feet and sometimes the teats of cows. These signs are encountered not only in cattle, sheep, goats, pigs and other cloven footed animals, but also in guinea-pigs infected by inoculation in the laboratory. It has been shown at Pirbright that unweaned white mice a few days old, when infected with the virus of foot-and-mouth disease, develop muscular paralysis and heart lesions and die within a day or two. Although the disease in mice is manifestly different from that in adult cattle, it is similar to that encountered in young calves, piglets and lambs. Pathological studies have been made of the degenerative lesions in the heart and skeletal muscle associated with virus infection and it has been shown that other organs e.g. the pancreas may also be affected.

Again similar studies made more recently in adult guinea-pigs have shown that lesions may be formed at other more unusual sites, e.g. the oesophagus; pancreas; prepuce; perineum and vulva in pregnant females; and teats, in pregnant and lactating females. The factors, including the effect of hormones, which influence the distribution and severity of these lesions are now being investigated.

Studies of virus infected tissues with the aid of the electron-microscope are now in progress and it is hoped shortly to begin work on cytopathological chemistry.

Vaccines and Vaccination. Reference has been made to the installation of a vaccine production unit and the general purpose for which it has been provided. In the past fifteen years much fundamental work has been done at the Institute on the preparation and testing of vaccines for safety and protective powers. The preparation of different vaccines has always been on a relatively small scale. Large scale production raises a number of further problems which are now being investigated, with a view to developing improved, cheaper and more rapidly produced vaccines.

OUTCOME OF RESEARCH

The problem of controlling foot-and-mouth disease is one for international collaboration, as was stressed by the Departmental Committee on Foot-and-Mouth Disease in its report 1952-54. The Institute is making many useful scientific contributions towards the main and urgent aim of more effective control, so as to reduce the world wide incidence of the disease and ultimately to eradicate it from many countries in which (as it is not in Britain) the disease is endemic.

A report on the work of the Institute is published from time to time.

ANIMAL DISEASES RESEARCH ASSOCIATION

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Following the First World War the initiative of a number of Scottish farmers led to the formation of the Animal Diseases Research Association. In 1921 the Association, with financial help from the Development Commissioners, set in hand the research work which developed into the Institute as it is to-day. At first the research staff were housed in two small rooms in the Glasgow Veterinary College. By 1926 they were able to move to the present site at Moredun on the southern outskirts of Edinburgh, where laboratories, animal houses and pasturage were provided for an expansion of the work. Since then the buildings have been considerably extended. In particular a new laboratory wing, mainly for parasitological research, was completed in 1955 and a virus unit is almost ready for occupation. Also in recent years further animal accommodation has been built and as many as 1,200 experimental sheep can now be held at any one time.

On 31st March, 1957, the scientific and experimental staff of the Institute numbered twenty-six.

Although fundamental research is done, the principal research work of the Institute is devoted to the investigation of specific diseases and to the attempt to discover means to prevent or cure them.

CURRENT WORK

Microbiology. This department is concerned with Johne's disease of cattle and sheep, scrapie disease of sheep, virus abortion of sheep, sheep pneumonia and the tick-borne infections.

In Johne's disease it would appear that there are various grades of host resistance to the causal organism and that clinical symptoms are not so much dependent upon the presence of the organism, which may be ubiquitous in an infected herd, as upon inadequate immunological response in certain animals. In consequence an attempt is being made, using a number of techniques, to investigate the different host responses not only to natural infection but also to vaccination.

With scrapie it has been shown that the disease can be transmitted serially in sheep by inoculating material taken from the central nervous system and other tissues of both natural and experimental cases of the disease. The fact that temperatures around 100°C. acting on such inocula fail to destroy the agent suggests that the causal factor is an unusual one and a considerable effort is being made to determine its nature and its pathogenicity. Since the clinical symptoms of scrapie have not as yet been explained on any satisfactory pathological basis, a study of the pathology of the disease is being undertaken. Field

evidence strongly suggests that scrapie runs in certain breeding lines: its possible genetic origin is, therefore, being investigated in an experimental flock.

The causal virus of enzootic abortion of sheep having been recently discovered and a satisfactory vaccine developed, the present work in this field is concerned with the duration of the immunity induced by the vaccine.

Biochemistry. The department's main effort is concentrated on an investigation into the etiology and chemistry of hypomagnesemia and copper deficiency disease. In the British Isles these two conditions appear to present similar problems since, according to current theories, they are both caused by factors which inhibit the use of an essential element, i.e. magnesium or copper. As a consequence the investigation of both conditions is developing along parallel lines in that the adequacy and availability of the elements in those pastures which induce the diseases, the mechanism by which magnesium and copper are used by the animal and the forms in which they are present in body fluids are all being investigated.

Physical Chemistry. This department is mainly concerned with the nature of the transmissible scrapie agent, although preliminary work on some aspects of immunochemistry has begun.

Parasitology. This department is working almost entirely on the gastro-intestinal worms of sheep and cattle. As the evidence on the effect of physical factors on the developmental dynamics and survival of the free-living phases of many gastro-intestinal worms is incomplete and confused, an investigation has been undertaken into the effects of temperature, oxygen tension and water relations upon embryonic development, larval development and survival, larval translation and behaviour, and the biotic relationships and infectivity of third-stage larvae. Work is also being carried out on host relationships, which involves the detailed investigation of the resistance and immune responses and their significance in the phenomena of "spring rise" and "self-cure". It is the intention that the findings from these investigations will be used to interpret occurrences in the field and to formulate control recommendations.

In addition to the above laboratory investigations ground at the Institute is being used for studies on the build-up, maintenance and seasonal variations of worm populations in closed environments, especially with reference to the parasite *Nematodirus*.

Pathology. This department co-operates with other departments, and is concerned also with an investigation into the numerous osteodystrophic diseases of farm animals.

OUTCOME OF RESEARCH

Not more than thirty years ago, there were in Britain nineteen major diseases of the sheep of which the cause was unknown. To-day, in eighteen of these diseases the cause has been demonstrated and in fourteen of them specific means for cure or prevention have been evolved. In the elucidation of ten of these problems Moredun Institute has been intimately concerned.

During recent years the causal agent of enzootic abortion of ewes has been demonstrated and shown by workers at Moredun, in collaboration with the Veterinary Investigation Officer, Edinburgh and the East of Scotland College of Agriculture, to be a virus of the psittacosis group. An effective vaccine against the disease has been prepared using virus grown on fertile hens' eggs so that another disease of sheep known for many years on the farms of south-east Scotland is now controlled. Further, through the discovery of the causal virus and the development of a serological test for diagnosis, it is now known that the disease is not uncommon in many areas of Britain and is present in the sheep flocks of several European countries.

The results of research in other problems over the past few years have also had a practical bearing on field problems. The demonstration, again in collaboration with the Veterinary Investigation Officer at Edinburgh, that the parasitic worm *Nematodirus* is an important pathogen of lambs, was followed by field observations and laboratory experiments on the life-history of the parasite. This work has now provided sufficient information for the control of the disease by pasture management. More recently similar work on the ecology of the free-living phases of other gastro-intestinal worms of sheep suggests that the accepted principles regarding controlled grazing against worm infestations may need revision.

In a different field, work on contagious abortion of cattle has shown that a new oil adjuvant vaccine prepared with a killed strain of *Brucella abortus* gives a very high degree of protection to guinea pigs when challenged with a virulent field strain of *Br. abortus*. Such a vaccine has the advantage of not producing a positive agglutination reaction and therefore offers a possible method of using vaccination in combination with an eradication programme. Further work using experimental cattle is required.

Finally, the demonstration of the fact that scrapie disease of sheep can be experimentally transmitted may become of practical importance. The considerable resistance of the agent to physical and chemical agents is of scientific interest.

The Animal Diseases Research Association publish an Annual Report concerning the work of Moredun Institute.

ANIMAL PHYSIOLOGY AND NUTRITION

THE ROWETT RESEARCH INSTITUTE

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B.S.A., D.Sc., F.R.S.E.

J. Davidson, B.Sc., Ph.D., A.R.I.C.
Miss G. M. Ellinger, B.Sc., Ph.D., A.R.I.C.
R. Hill, B.Sc., Ph.D.

C. F. Mills, M.Sc., Ph.D., A.R.I.C.
A. A. Woodham, B.Sc., Ph.D.

APPLIED NUTRITION

Head of Department: J. A. Crichton,
M.B.E., M.A., B.Sc. (Agric.)

J. L. Corbett, B.Sc. (Agric.),
M.Agric.Sci. (N.Z.)
I. A. McK. Lucas, B.Sc. (Agric.), M.Sc.
T. R. Preston, B.Sc. (Agric.), Ph.D.

STATISTICS

Head of Department: A. W. Boyne, B.Sc.

DUTHIE EXPERIMENTAL STOCK FARM
W. Thomson

Secretary: W. Middleton, N.D.A.

Librarian: W. L. Simpson, M.A.

The Institute was established in 1914 in temporary accommodation at Aberdeen University for research in animal nutrition. After the First World War, a generous gift from the late Dr. John Quiller Rowett and a grant from the Development Commission enabled a new building to be erected and this was opened in 1922.

Within the last ten years the laboratories, experimental houses and ancillary services have been reconstructed and considerably extended, and a new storey has been added to the main laboratory block. As a result the laboratory and experimental animal accommodation has been practically doubled. Special, though very limited, accommodation is provided for work involving surgery, X-radiography, U-V phase contrast microscopy, stable and radioactive isotopes, direct calorimetry and other metabolic and environmental studies. The farm of the Institute, the Duthie Experimental Stock Farm, extends to just over 500 acres.

On 31st March, 1957 the scientific and experimental staff of the Institute numbered eighty-five.

The work is directed to the advancement of our understanding of the energy and material requirements of animals of agricultural importance so as to enhance the quality and quantity of their production to meet the needs of man. This involves the systematic investigation of the nature of the foodstuffs eaten, their changes during the course of digestion and the absorption and metabolism of the products of microbial activity and digestion. A study is also made of the relationship of diet to metabolic disorders and other underlying causes of susceptibility to disease. On the basis of the new knowledge obtained and of researches elsewhere, exploration is made of the best systems of feeding livestock, particularly from home-produced foodstuffs, and of the influence of environment on the utilisation of foodstuffs. At the same time man's requirements for animal foodstuffs are kept continually under review. The close association with the Institute of the Commonwealth Bureau of Animal Nutrition, which publishes *Nutrition Abstracts and Reviews* and various technical communications, provides a valuable information service.

CURRENT WORK

Protein and Lipid Chemistry. The work of this department relates to the chemistry of proteins and lipids, the fate of food in the animal, and special techniques and facilities. Considerable progress is being made in the characterisation of the protein and non-protein nitrogenous constituents of grasses and other leaves and studies of plant peptidases are in progress. The plasma lipids, in farm animals under different physiological and nutritional conditions and the relation between lipids metabolism and tocopherols are also being investigated.

The present work on the ruminant is concerned with the use of protein in the diet during lactation in relation to other dietary constituents, such as fat and carbohydrates, and the proteinuria of the very young animal.

Methods using adsorption and ion exchange chromatography with gradient elution are being developed and applied to the separation of enzymes, toxins and serum proteins. New equipment is being constructed and assembled to improve the freeze drying and isotope tracer facilities of the Institute.

Microbiology. This department is concerned with the isolation and identification of bacteria from the rumens of cattle and sheep on different diets, in an attempt to assess their distribution and importance in the metabolism of different animals. This work involves studies of the conditions under which these organisms will grow in pure culture, the enzymes produced, and the end products of the fermentations of different substrates. Serology is used to provide methods of identifying the organisms. Studies are also in progress on the isolation and properties of rumen protozoa, including the enzymes of these organisms and the part they play in rumen metabolism.

Enzymology. The work of the department is concerned with α -mannosidase and β -N-acetylglucosaminidase activities which are altered in mammalian tissues by sex hormones, and are of particular interest in the male genital tract. The latter enzyme is inhibited by 2-acetamido-2-deoxyglucuronolactone in very low concentration. The purification of β -glucuronidase has been greatly improved. This enzyme has been shown to act on β -galacturonides. It is inhibited by traces of cuprous ion, and thiol and disulphide groups appear to be essential for activity. Hydrolysis of cellulose by rumen micro-organisms requires at least three distinct enzymes, a labile depolymerase, a β -polyglucosidase and cellobiase, all of which have been obtained in cell-free preparations.

Physiology. The department's work centres on the problems presented by certain metabolic diseases of ruminants, the rearing and housing of young pigs and the significance of the heritable physiological variations of ruminants. Individual subjects that are being studied are: the salivary secretions of young

and adult ruminants and their reflex control; the reflex activity of the alimentary tract of sheep; rumination and diet; the mechanism and absorption of inorganic ions from the stomach and gut of sheep; the fate of ammonia found in the rumen; the intermediary metabolism of the short-chained fatty acids absorbed from the rumen and large intestines; the heat evolved by young pigs kept at different environmental temperatures using a gradient layer calorimeter. Finally a study is being made of sheep of the same breed distinguished by genetic characteristics of the red blood cells under different environments. The metabolic diseases forming the background of much of this work are "bloat", "lactation tetany" and "ketosis".

In the *Director's Unit* work covers the study of the changing composition of the digesta throughout the alimentary tract of the ruminant, in particular the marked rise in nitrogen content of the first part of the small intestine; the effect of mode of killing on the degree of shedding of the intestinal epithelium; the effect of trauma on nitrogen and energy metabolism; and the metabolism of the plasma proteins.

Pathology. This department is concerned with the investigation of host-parasite relationships with particular reference to diseases of animals and man caused by pathogenic bacteria and parasitic helminths. The aim is to discover exactly how these organisms produce disease, and to investigate possible means of prevention. Work is in progress on the effects of antisera on bacterial growth; immunity to *Corynebacterium pyogenes* mastitis; the mechanism of antibody production; the purification of bacterial toxins; and immunity to tuberculosis and to helminths.

Applied Biochemistry. Work is going on in the attempt to get more accurate laboratory methods of measuring the nutritive value of feeds as a step towards more economical animal feeding and, hence, towards reduced feed imports. More accurate methods of assessing energy and protein values for non-ruminant feeds have been designed and are being used to devise more economical rations for pigs and poultry.

Protein concentrates have been found to be very variable in the quality of their protein, much of this variability arising from damage during processing. A collaborative trial, involving official and commercial research laboratories here and in the U.S.A., is in progress to devise rapid laboratory tests of protein value that will allow the grading of protein concentrates offered for sale and the improvement of manufacturing methods.

The nutritive value of feeds and grazings is being assessed by examination of the living animal. The mineral status of the bone is assessed by X-rays. The protein and fat content of the animal are assessed by other suitable methods.

The availability of copper in herbage and of substances interfering with its use are also being studied.

Applied Nutrition. The following studies are in progress in this department:—the nutritional requirements of early weaned pigs, calves and lambs; long-term experiments on the effect of the level of feeding of dairy heifers and sows from birth to first parturition on their subsequent fertility, health and production; the effect of the feeding and implantation of oestrogens, mainly hexoestrol, on growth and carcass composition of cattle, sheep and pigs; the interaction of plane of nutrition, environment and breed on the production and quality of bacon pigs; methods of extending the grazing season and the effects of restricting concentrate feeding to grazing cows; techniques for estimating the consumption and digestibility of pasture herbage so that the productivity of both grazing animals and pastures may be evaluated.

Metabolism. In this department the nutrition of the breeding ewe during pregnancy and lactation and its effect on lamb production are being studied.

Duthie Experimental Stock Farm. An investigation is being made into the value of heather to the grazing sheep.

Statistics. This section is concerned with the design and analysis of experiments for other research workers; the study of sampling methods and techniques involved in research work; and the interpretation of radiological data related to mineral requirements of sheep.

OUTCOME OF RESEARCH

Some results of practical importance relating to nutritional disease and feeding practice are:—

- (a) Enzootic muscular dystrophy in calves in the North of Scotland is not associated with a high intake of unsaturated fatty acids in the milk fat but with a gross deficiency of tocopherol in the milk of beef cattle on the traditional diet of straw and turnips.
- (b) Processing of the animal feeding stuffs has been found sometimes to affect adversely the value of the protein for dairy animals and a practical feeding experiment on this effect is in progress at present at the A.R.C. Field Station, Compton.
- (c) Work on protein quality in protein-rich concentrates should allow manufacturers to develop superior processing methods and to market quality-graded products. This should promote more economical feed formulation by farmers and compounders, thus reducing imports.
- (d) Certain bone and dental disorders of sheep can be diagnosed and the effect of treatment assessed by radiography with a mobile X-ray unit.
- (e) The diets and methods of feeding and housing as recommended by this Institute for the early weaning of pigs and calves have been adopted in practice.
- (f) The implantation of hexoestrol in certain classes of stock is being tried out by many farmers.
- (g) The work on the production of high grade bacon has been of considerable importance to the pig industry.
- (h) Experiments on the conservation and management of grass for winter grazing have contributed to the now widely recommended use of the "late bite".
- (i) The incidence of pregnancy toxæmia is reduced by pre-lambing supplementary feeding; and the milk yield of ewes, weight of lambs at weaning and survival rate to weaning are increased more by pre-lambing supplementary feeding than by the feeding of supplements after lambing.

Other work of particular interest concerns the role of facultative anaerobic bacteria of the rumen in digestion and the enzyme systems of holotrich protozoa in rumen metabolism; a general relationship between chemical structure and the inhibition of enzymes that remove sugar residues, which enables powerful enzyme inhibitors to be prepared and used in work on enzymes concerned in reproduction and in cellulose hydrolysis in the rumen; the development and use of the gradient layer calorimeter, which is the only one of its kind used in farm animal research, in energy studies on pigs; the study of the incidence of two heritable characters of the erythrocytes of sheep which have a marked geographical distribution; the considerable addition of nitrogen to the digesta of the first part of the small intestine and the significance of the changes in the epithelium after humane killing and the finding that the increase in heat production following injury is due almost entirely to the oxidation of protein; the

experimental production of enterotoxaemia of sheep and the knowledge obtained of the various predisposing causes, which should be useful in devising more adequate methods of control; the study of organic copper complexes in their bearing on copper deficiency; and finally the research by the Statistics Section showing the value of repeated observations in biological sampling, with particular reference to blood measurements on twin cattle.

The Institute publishes annually a summary of the year's papers together with a review of progress on two aspects of the Institute's work.

A.R.C. INSTITUTE OF ANIMAL PHYSIOLOGY

Babraham, Cambridge

Director: I. de Burgh Daly, M.A., M.D., F.R.C.P., F.R.S.

Deputy Director: Sir Alan N. Drury, C.B.E., M.A., M.D., F.R.C.P., F.R.S.

PHYSIOLOGY

Head of Department: I. de Burgh Daly,

M.A., M.D., F.R.C.P., F.R.S.

J. Bligh, B.Sc., Ph.D.

G. Fegler, M.D.

Miss C. O. Hebb, M.A., Ph.D.

K. J. Hill, M.V.Sc., M.R.C.V.S.

J. L. Linzell, B.Sc., Ph.D., M.R.C.V.S.

L. E. Mount, M.D., C.M., M.B., B.S.

J. S. Perry, B.Sc., Ph.D.

I. W. Rowlands, M.Sc., Ph.D.

BIOCHEMISTRY

Head of Department: Sir Rudolph Peters,

M.C., M.D., F.R.C.P., F.R.S.

E. F. Annison, B.Sc., Ph.D., A.R.I.C.

R. M. C. Dawson, B.Sc., Ph.D.

D. Lewis, M.A., M.Sc., Ph.D., A.R.I.C.

D. B. Lindsay, M.A., B.Sc., D.Phil.

P. F. V. Ward, B.A., B.Sc.

V. P. Whittaker, M.A., D.Phil.

EXPERIMENTAL PATHOLOGY

Head of Department: Sir Alan Drury,

C.B.E., M.A., M.D., F.R.C.P., F.R.S.

A. D. Bangham, M.B., B.S., M.R.C.S., L.R.C.P.

B. Cinader, B.Sc., Ph.D.

E. J. H. Ford, M.V.Sc., M.R.C.V.S.

D. C. Hardwick, B.Sc., Ph.D.

A. E. Pierce, M.Sc., Ph.D., F.R.C.V.S., D.V.S.M.

Secretary: E. Norris, B.Comm.

Librarian: D. W. Butcher, M.A.

Farm Manager: T. M. Fulton

In 1945 the Agricultural Research Council, in reviewing their post-war programme, decided there was a pressing need for extending knowledge of the fundamental physiology of farm animals and that a new Institute of Animal Physiology should be set up. The Institute, situated six miles south-east of Cambridge, was started in 1948 and the buildings now include a library, laboratories for physiology, experimental pathology and biochemistry, accommodation for cattle, sheep, goats and pigs and other laboratory animals, two surgical theatres, a surgical anatomy and post-mortem block and engineering shops. Forty-six houses and cottages are available for the staff as well as a hostel and refectory. The farm of some 320 acres breeds and feeds the animals needed for experimentation.

On 31st March, 1957 the scientific and experimental staff of the Institute numbered fifty-four.

CURRENT WORK

An account of main lines of current investigation is given below. A more detailed account of the work of the Institute than can be given here has already been published (Proc. Roy. Soc. B, **146**, pp. 194-205, 1957).

Physiology. A study is being made in various animal species of the distribution of cholinergic nerve fibres in the central nervous system identified by the presence of enzymes controlling acetylcholine metabolism. It would appear that the distribution of choline acetylase is the most reliable guide to the distribution of cholinergic neurones. Studies on choline acetylase changes in the central and peripheral portions of a sectioned nerve suggest that the enzyme is manufactured in the cell body although only released in the endings. Electrophysiological, histological and chemical data obtained from nerves showing different degrees of degeneration produced by various means are accumulating. These investigations are of importance in relation to the underlying mechanisms governing the myopathies. Progress has been made towards obtaining a map of the enzyme system in the brain and a parallel investigation is the preparation of a comprehensive atlas of the sheep brain in stereotaxic coordinates with special reference to autonomic representation.

Using the thermodilution method developed at Babraham, it has been found that the cardiac output in the sheep amounts to $6 \frac{1}{2}$ l./min. ± 10 per cent, and the portal vein flow approximately 1 l./min. Attempts are also being made to develop a continuous method for recording blood flow. A further development is that together with the blood flow the heat production in various organs can be measured. In a study of carotid body reflexes in the dog it has been shown that a change from arterial to venous blood supplying the carotid body elicits a reflex intrapulmonary vasodilatation. In the sheep cardiac fibres originating in the thorax are recurrent not only within the caudal portion of the right cervical vagosympathetic nerve but also within the middle and lower segments of the thoracic sympathetic chains. Preliminary investigations have shown that the mammary blood flow in the conscious goat is 50–70 ml./100 g./min. in full lactation and 20–40 in dry animals: like the milk yield it is depressed by surgical operations and illness. Work is continuing on the innervation of the udder and on better methods of measuring udder blood flow. A study is being made of the blood supply to the brain of conscious sheep and goats.

A technique is being devised for permanently catheterising the portal vein for investigations on the absorption of metabolites from the rumen. The secretion of pancreatic juice in the sheep is being examined using a method which allows collection of juice in the conscious animal and the cerebro-spinal fluid is being investigated and attempts made to devise a method for repeated collection of C.S.F. from the same animal.

The induction of superfoetation is another problem. The sterile horn of unilaterally pregnant animals is being used for experiment. The difficulty of inseminating a pregnant animal with a sealed vagina has been overcome by injecting spermatozoa into the abdominal cavity. The optimal time of insemination in relation to ovulation and the minimal numbers of spermatozoa required to produce maximum fertility have been established. Prenatal mortality in sows is being estimated by counting corpora lutea at laparotomy early in pregnancy for comparison with numbers of young at birth. The persistence of corpora and possible formation of new ones during pregnancy is being studied.

The lack of blood-sugar homeostasis in the newborn piglet has led to an investigation of the mechanisms governing carbohydrate metabolism. As an initial approach alloxan diabetes was studied. The condition appears to be similar to that in other animal species. Further research aims at the determination of glucose utilisation rate, and the effects of environmental temperature and oxygen tension. Apparatus has been built for studying the central and sensory components of the mechanisms governing temperature regulation and preliminary experiments on sheep have been started.

Experimental Pathology. A study of shed blood perfusates for isolated organs and whole animals is being made in conjunction with the physiologists and pharmacologists. The presence of pressor substances and blood incompatibility are the main difficulties. Goat red cells suspended in albumin has been shown to be a satisfactory perfusion fluid for the isolated goats' udders judged by nerve responses and low oedema formation during eight hours perfusion. The failure of such an udder to make normal quantities of milk is under investigation. Reserpine would appear to have potentialities for removing pressor amines from both donor and recipient in perfusion experiments.

The problem of the compatibility of red cells has been investigated in sheep. The injected cells have been followed by labelling them with Cr^{51} and a test has been developed for the weak naturally occurring haemolysins. The fate of injected cells can be correlated with the absence or presence of a haemolysin and its strength. Transfusion in sheep under experimentation is sometimes valuable and the results should help in selecting suitable donor sheep. For a period a group were studying the blood groups of cattle but in July 1956 they moved to the Animal Breeding Research Organisation, Edinburgh.

Very little is known about the antibody response of goats and sheep, and an investigation on the nature of antibody to molecularly defined antigens is being undertaken. Acquired immunological tolerance has been demonstrated in small animals by the injection of defined antigen-molecules into new born animals. This work is being extended to include goats and sheep. The action of antibodies on enzymes is being investigated, to explore the mechanism by which antibody inhibits enzyme and the inhibitory quality of antibody produced in response to different methods of immunisation. This investigation may assist in therapeutic problems such as those presented by the immunologic attack on worm infestation. The local production of antibody by cattle is also being studied. The results have proved of practical importance as regards those organs which become specifically infected at their mucous surfaces. The changes in the serum proteins of pregnant cattle and in the neonatal calf with special reference to the transference of antibody are being continued and have been extended to a study of the proteins present in the urine of the neonatal calf.

The property of "stickiness" exhibited by reticuloendothelial and some other cells to bacteria and protozoa forms an important first line defence against many diseases. Using a technique for characterising the charged groups on the surface of colloidal particles, an investigation into the mechanism of "stickiness" or phagocytosis has been carried out in association with the Department of Colloid Science in the University of Cambridge. The survey of the electrophoretically different haemoglobins started in British cattle breeds has now been extended to cover the important commercial breeds in France, Switzerland, Denmark and Africa.

An investigation on cattle is under way to discover whether the effects of the stress of pregnancy, parturition or lactation can be detected by variations in the serum bilirubin and alkaline phosphate levels and by examination of liver biopsy material.

Biochemistry. Much of the work of this department covers the metabolism of the rumen, and in particular the metabolism of the lower fatty acids, especially the biochemistry of acetic acid and allied substances. In addition work has been done on phospholipid metabolism, particularly in relation to the behaviour of such compounds in ram semen, and an assessment with radioactive isotopes of the rate of passage of sperm through the epididymis. In these connections protein-carbohydrate interrelationships have been studied in the rumen, and carbohydrate-acetic acid relationships in isolated heart preparations. Interesting information about one aspect of the problem of "bloat" was obtained when the

changes in the concentration of several metabolites in blood and rumen were examined after turning out animals on to lush pasture; in relation to this, studies on portal blood withdrawn by permanent catheter have proved valuable. The levels of ammonia which are toxic in the general circulation have been investigated, as it is evident that the sheep liver must continually "monitor" ammonia passing into it from the rumen by way of the portal vein. A start has also been made on the study of some rumen protozoa and bacteria; the greater understanding of metabolism within the rumen which will be gained should make it possible to consider ordinary feeding trials more intelligently.

Studies of the behaviour of fluorine derivatives of various organic acids are relevant to this as they interfere with the working of the tricarboxylic acid cycle. Special point has been given to the study of fluoroacids by the identification of fluoracetic acid as the active principal of the plant *Dichapetalum cymosum* which poisons cattle in South Africa. The research is also directed to finding possible antidotes and protective substances to help the S. African farmer. An intensive study of synthetic fluorocitric acid has proved necessary. These researches have been extended to the finding of a fluorofatty acid in an allied species (*Dichapetalum toxicarium*) in the Sierra Leone district, and to a more general study of the metabolism of other carbon-fluorine compounds which show surprising differences in metabolic behaviour. (It may be noted that American workers have recently found that a fluoroarotic acid is anticarcinogenic.) Attempts are being made to study the toxic compounds in other species of the same genus in East Africa, which could conceivably poison livestock. Experiments are also being continued on fluoride-treated grass patches at Babraham to make sure that grasses in this country cannot synthesise small amounts of CF compounds. The problem must be distinguished clearly from that of fluoridation.

It has been demonstrated that the sheep degrades thyroxine much faster than man and that, as might be expected, cold induces a larger utilisation of thyroxine. Studies are now being made of the effect of pregnancy, though preliminary work indicates that any changes are small. It is too early to say whether the use of thyroxine after shearing would be of value; but results obtained suggest that this may be so.

Work is also in progress on the metabolism of various homologues of acetylcholine and on the new physiologically active ester dimethylacrylyl choline recently isolated in this department.

A.R.C. UNIT OF EMBRYOLOGY

**Department of Zoology, University College of North Wales,
Bangor, Caerns**

Honorary Director: Professor F. W. Rogers Brambell, B.A., D.Sc., F.R.S.

(Professor of Zoology, University College of North Wales)

Senior Scientific Officer:

W. A. Hemmings, B.A.

Research on reproduction and prenatal mortality in wild rabbits was supported by special research grants from the Agricultural Research Council for a number of years before the Unit was established. This research led to experimental studies on the transmission of immunity from mother to young in tame rabbits and to related fundamental physiological and embryological investigations bearing on the immunity and nutrition of the foetus. In 1953 the Unit was

set up with the concurrence of the University College of North Wales, Bangor, to provide for the development of this research on a long-term basis under the direction of Professor F. W. Rogers Brambell, F.R.S.

The Unit was housed in new laboratories of the Department of Zoology and given the use of a new Animal House. It is equipped for surgical and serological work on small mammals and for radioactive isotopic techniques.

CURRENT WORK

The young animal derives its immunity to disease from the mother. Antibodies produced by the mother are transmitted to the young animal either before or after birth or both. They belong to the β -globulin fraction of the circulating serum proteins. Their transmission before birth, as in man, rabbit, guinea-pig, rat and mouse, involves the transport of these large protein molecules across the foetal membranes without losing their specific biological activity. Their transmission after birth, as in ruminants, pig, horse, rat and mouse, involves secretion in the colostrum or milk and transport from the alimentary tract to the circulation of the suckling. The precise route and mechanism of transport present problems of fundamental physiological interest.

The transmission of immunity is also of practical importance in relation both to medical and veterinary science, for on it depends the resistance of the young to disease. Haemolytic disease of the newborn occurs in man, the horse, and the pig and possibly other animals and is directly due to the transmission of maternal antibodies that react with the red blood corpuscles of the young animal. Moreover antibodies alone constitute readily recognisable elements among those serum globulins which may be transmitted and are functionally important to the young animal in other ways.

Studies by members of the Unit on the transmission of immunity in the rabbit, where it occurs entirely before birth as in man, showed that it took place by secretion into the cavity of the uterus and transport across the yolk-sac of the foetus, not by way of the placenta as had been generally assumed. The mechanism of transport across the yolk-sac of the foetal rabbit was found to be selective in that, when the yolk-sac was experimentally exposed to antibodies derived from other species, the facility with which transmission to the circulation occurred was characteristic of the species of origin of the antibody. This selective transmission of immune globulin was considered to be of sufficient interest to warrant intensive study.

Accordingly researches were undertaken to determine whether a similar selectivity could be demonstrated in other animals. It was found that in the chick transmission of immunity, which occurs by way of the yolk-sac, takes place mainly in the first few days after hatching. The yolk-sac of the day-old chick was found to display a similar selective transmission of antibodies derived from other species. Transmission in the rat occurs partly before birth but mainly after birth. It was found that transmission before birth occurs both by way of the yolk-sac and the foetal gut. Transmission after birth in the rat by way of the colostrum or milk and the gut of the young animal was found to display selectivity. Thus in all these animals transmission occurs across an entodermal membrane and is selective.

These researches are being extended. Labelled protein molecules are being used to investigate the many problems involved. Antibodies provide such labelled molecules, recognisable by their specific biological activity when introduced into animals which are not immune. Radioactive isotopes which can be attached to the molecules provide another means of marking them. The use of the two methods singly or in combination is providing a powerful and flexible technique for probing the cellular mechanisms involved in transport by the entoderm.

A.R.C. UNIT OF MICROBIOLOGY

Department of Microbiology, The University, Sheffield

Honorary Director: S. R. Elsdén, B.A., Ph.D.

(Senior Lecturer in Microbiology, Sheffield University)

Senior Scientific Officer: J. L. Peel, B.A., Ph.D.

From 1948 until 1952 the Council made annual grants to Sheffield University in aid of the microbiological research conducted by Dr. Elsdén. In 1952, in order to provide greater continuity, the Council decided to establish a Unit of Microbiology at the University. The Unit undertakes fundamental research on micro-organisms of interest to agriculture.

CURRENT WORK

Four main lines of work are in hand, the metabolism of anaerobic bacteria, the metabolism of aerobic bacteria, the metabolism of photo-synthetic bacteria and the continuous culture of bacteria.

One particular anaerobe (rumen organism LC), which has been isolated from the rumen of the sheep, has been selected for intensive study because it is unique in growing anaerobically on either lactic acid, glucose or fructose from which it makes acetic, propionic, *n*-butyric, *n*-valeric and *n*-caproic acids, along with hydrogen and carbon dioxide.

The mechanism of pyruvic acid breakdown has been studied. Cell-free extracts of the organism have been prepared which rapidly convert pyruvic acid to acetyl phosphate, hydrogen and carbon dioxide. Evidence has been obtained that a hitherto unknown co-factor is required for the utilisation of pyruvic acid by this organism. The co-factor is present in boiled extracts of LC and also in boiled extracts of other strict anaerobes such as *Clostridium butyricum*. Methods are being worked out for the separation and purification of this new co-factor. The properties of the purest preparation so far obtained are consistent with it being a nucleotide. The co-factor has a very limited distribution and the best source, to date, is the organism LC. The supply of LC limits the progress of the work. The largest scale on which LC has as yet been grown is 40 l. from which 30-40 g. dry wt. of cells are produced, and from which only a few mg. of co-factor concentrate are obtained.

A specific method has been developed for the separation and estimation of the various flavins in which LC is rich, and, a survey has been conducted of the distribution of flavins in a wide range of micro-organisms. The results of this survey confirm the association of flavins with fatty acid metabolism.

L-threonine deaminase of LC has been purified about 100 times. It has been found that freeze drying the enzyme in the presence of glutathione and ammonium sulphate inactivates the enzyme. Activity is restored by pyridoxal-phosphate, long thought to be a co-enzyme of this enzyme. This is the first direct demonstration that a bacterial threonine deaminase is a pyridoxal phosphate enzyme.

An investigation has started of the mechanism of the fermentation of lactic acid and acrylic acid by LC. Cell-free extracts of LC have been prepared, which ferment these two acids to hydrogen, carbon dioxide, acetic and propionic acids. The present indications are that the reaction is exceedingly complex.

The work on the metabolism of aerobic bacteria has been carried out with *Pseudomonas fluorescens*, an aerobic organism present in soil. Early work on this organism was concerned with the mechanism of oxidation of various organic compounds. An important finding was that the entry of organic substrates into this organism is an energy requiring process and is mediated by

specific proteins. During the past year, one of the respiratory pigments has been purified and its properties have been studied. The pigment is a cytochrome, related to but not identical with cytochrome c of heart muscle.

The work on the metabolism of photosynthetic bacteria has involved the green sulphur bacterium *Chloronium thiosulphatophilum*, and from this organism a cytochrome pigment has been isolated. The isolation of this pigment is of considerable theoretical importance. Similar pigments have been found in other photosynthetic bacteria. These are all able to grow in the dark if provided with oxygen, and it was impossible to say whether the pigment was peculiar to the photosynthetic apparatus. *Chl. thiosulphatophilum* is a strict anaerobe, being killed by exposure to oxygen. The isolation of a cytochrome from such an organism suggests that these pigments are playing a part in photosynthesis. The preparation appears to be pure; it contains 0.37 per cent iron, but it has not been subjected to analysis on the ultra-centrifuge. The iron content of the preparation and the redox potential have been measured.

The metabolism of organic compounds by the purple photosynthetic bacterium *Rhodospirillum rubrum*, has also been studied. In particular, the metabolic pathways of both propionic and butyric acids have been studied. The results so far obtained from the work on butyric acid metabolism suggest that propionic acid is assimilated via succinic acid and that butyric acid is first broken down to a *n*-carbon fragment which then combines into carbon dioxide. A systematic study has also been made of the effect of inhibitors, in particular, cyanide, arsenite and hydroxylamine on the light metabolism of this organism. In general, the extent of the inhibition by cyanide is related to the amount of carbon dioxide fixation. With substrates, of which the metabolism is associated with only a slight carbon dioxide fixation, e.g. acetic acid, the overall metabolism is only slightly inhibited by cyanide: with substrates of which the metabolism is associated with a high carbon dioxide fixation, the degree of inhibition by cyanide is large, e.g. of the order of 90 per cent.

The first stage in the digestion of the food eaten by ruminants is carried out by the vast population of micro-organisms present in the rumen. All the major components of the diet, e.g. cellulose, pentosans, starches, sugars and proteins, are attacked by the micro-organisms and converted to simple substances which are absorbed into the blood stream and used by the animal. The breakdown of cellulose is of particular importance since this major constituent of the diet is not attacked by conventional digestive enzymes. This fermentation, as well as bringing about digestion of the food, also provides energy for the growth of the micro-organism and in this way the population is maintained. The importance of these micro-organisms to the ruminant is thus obvious. Since there is an almost continuous passage of materials through the rumen, and since the daily rate of inflow approximately equals the rate of outflow, the rumen bacteria grow as in continuous culture. Over the past ten years, methods have been developed for growing single species of bacteria in continuous culture and much useful information has been obtained on the factors controlling the size of the population and on the properties of organisms grown under these conditions. A simple and effective apparatus for growing bacteria in continuous culture has been built in the Unit with the object of studying the rumen population under controlled conditions.

Because of the complexity of the rumen population, and because at present we have so little information on the properties of the individual members of the population, it was considered advisable, in the first instance, to work with a single species. *Streptococcus faecalis* was chosen for this purpose. The organism resembles closely the rumen organism *Streptococcus bovis* and like rumen bacteria it grows vigorously, under anaerobic conditions. It obtains its energy

for growth by converting glucose to lactic acid. The investigation with this organism has so far dealt with the factors which influence the amount of glucose fermented by a population, the density of which is controlled by the concentration of a single growth factor—tryptophan. It has been found that the rate of fermentation of glucose is not controlled in any way. Cells always ferment at the maximum rate irrespective of the energy requirement of the cells. It is next proposed to examine the effect of long generation times—of the order of 24 hours—on the metabolic activities of the organism. Long generation times are of particular interest because, from the rate of flow through the rumen, it is clear that the organisms there must have mean generation times of this order. It is hoped that the work will lead to a better understanding of the rumen population. These studies have already shown the importance of the technique of continuous culture, which is not only a most useful research tool but is also likely to be of importance in the production of biological materials.

DAIRYING

THE NATIONAL INSTITUTE FOR RESEARCH IN DAIRYING

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Deputy Director: A. T. R. Mattick, B.Sc., Ph.D.

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J. W. G. Porter, M.A., Ph.D.

S. Y. Thompson, Ph.D., D.Sc.

ISOTOPES

Head of Section: R. F. Glascock, B.Sc., Ph.D.

STATISTICS

Head of Section: C. P. Cox, M.A.

Miss P. M. Clarke (Mrs. Cox), M.A.

PHYSIOLOGY

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DIRECTOR'S LABORATORY

R. H. Smith, B.Sc., Ph.D.

LIAISON UNIT

W. G. Wearmouth,

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Secretary: H. F. Burgess, M.B.E., A.C.I.S.

Librarian: Miss D. Knight,
B.A., F.L.A., Dip. Lib.

The Institute was established at the University of Reading, with the aid of funds from the Development Commission, in 1912. Shinfield Manor estate, which included a farm of about 400 acres, was purchased in 1920, and the Institute moved there between 1920 and 1923.

By 1933 it became clear that without a strengthened research staff, more and better-equipped laboratories and other additional accommodation and an increase in the number of animals available for dairy research, the research programme of the Institute would fail to keep pace with the needs of the dairy industry both for new scientific knowledge and for the solution of current problems. With the aid of subscriptions and grants from public funds, a new library building, an extension to farm buildings, a small machinery testing shop and laboratory, and a laboratory block were provided between 1934 and 1938. In 1942 an artificial insemination centre was erected and in 1944 a new building was put up to house the Dairy Engineering department. After the Second World War a series of temporary laboratories and various other buildings were erected and in 1947 a second farm, Arborfield Hall farm, was acquired. An experimental cowhouse to hold 100 animals, and designed and equipped for milking research, was completed in 1953. In 1956 a building to house the boilers and electrical equipment for the Institute was completed, and a start was made on the erection of a laboratory block to provide accommodation for the overcrowded Bacteriology and Chemistry departments.

The Institute's research covers two classes of problem:—

- (a) the more immediate technical problems arising in connection with both milk production and milk utilisation;
- (b) the basic scientific questions associated with these technical problems, questions which usually have a bearing on future advances in the fields of milk production and utilisation.

On 31st March, 1957 the scientific and experimental staff of the Institute numbered ninety-seven.

CURRENT WORK

Raw milk and some milk products are highly perishable foodstuffs, and many of the problems of industrial utilisation of milk are an immediate legacy of action taken or not taken by the milk producer. For this and other reasons, it is not possible to deal with the problems of the dairy industry in two parts, sharply separated at the farm gate. From the earliest days of the Institute the scope of its work has therefore followed milk and milk products through from production to consumption, but for convenience in outlining the Institute's research the farm problems and the utilisation problems are described separately.

Milk production problems. The technical problems of dairy farming which concern the Institute arise in relation to dairy farm management, the growing and conservation of suitable crops for feeding dairy cattle; the assessment of the value of different feedingstuffs and of different methods of grassland management for milk production; milking systems and milking machine design and technique in relation to milk yield and udder infection; farm buildings, machinery and equipment specifically concerned with milk production. The more basic problems associated with milk production include studies of ruminant digestion, particularly in the bovine animal; the nutrition and metabolism (including abnormal metabolism) of young and mature dairy stock; the control of reproduction and lactation in the bovine; the biochemistry of milk formation in the udder; the various factors affecting milk yield and quality; the bacteriological aspects of milk production; analytical methods and the detailed composition of milk; the nutritional value of milk constituents and the origin of the vitamins in milk.

Milk utilisation problems. The technical problems of milk utilisation which the Institute studies, sometimes in collaboration with industrial firms, include the processing of liquid milk by heat treatment of various kinds, and the effect of such treatment on the hygienic quality and the keeping quality of the product;

other possible methods for improving the keeping quality of liquid milk; cheese-making and packaging by new methods; the mechanism of cheese ripening; physical and other methods for controlling cheesemaking technique; improvements in the manufacture of dried milk; chemical sterilisation and detergency in the dairy industry; and the testing of machinery and equipment to be used in the milk utilisation industry. The more basic problems relating to milk utilisation include the detailed investigation of starter organisms and their bacteriophages; a study of the antibiotics (nisins) produced by organisms occurring in milk; the taxonomy of the lactobacilli and other bacteria concerned in dairying; new tests for effective heat treatment of milk; the physics of milk, cream and butter; and the effect of processing on the nutritional value of milk, particularly on its vitamin content.

The Institute is divided into eight departments and five smaller sections or units. In the following paragraphs current work is listed under departmental, etc. heads, although the majority of the researches in progress are collaborative between two or more departments or units.

Dairy Husbandry

Machine milking studies. Vacuum level and milking rates; inheritance of milking rate; the effect of pulsation rates and ratios on milking rate; lactation yield and milk quality.

Environment, milking technique and udder infection. Effect of milking machine vacuum; effect of design of teat-cup on udder health; dry period infections.

The rate at which milk is secreted into the udder.

Dairying agronomy. Comparison of three grasses in terms of milk output; the value of supplemental feeding in the prevention of hypomagnesaemia and grass tetany; control of herbage maturation; liveweight changes of milking cows; conservation of feedingstuffs; the use of sodium metabisulphite in silage making; the effect of temperature on silage quality; the efficiency of different methods of haymaking; the storage of wet brewers' grains; silage feeding and milk yield and quality.

Collection of one-egg twin calves and diagnosis of monozygosity.

Experimental work with pigs. The feeding of milk by-products to pigs; other nutritional work, using antibiotics, hormones and other agents administered by mouth.

Feeding and Metabolism

Factors affecting the efficiency of food utilisation by cattle. The influence of the level of roughage in the ration on the fat content of the milk; the effect of changes of diet on the function of the reticulo-rumen; the effect of the level of roughage during rearing on the digestive efficiency of the adult; the measurement of body composition by dilution techniques.

Hypomagnesaemia and grass tetany. The effect of fertiliser treatment.

Feeding, milk yield and milk quality. Influence of plane of nutrition of in-calf heifers and of heifers in milk; concentrate feeding at different production levels; effect of supplementary feeding on the grazing cow; the nutritive value of ammoniated molasses.

Hormones and milk production. The effect of oestrogens on the yield and composition of cow's milk; the influence of growth hormone.

Calf nutrition and the significance of colostrum. Comparison of spray dried skim milk and fresh skim milk; the effect of feeding egg on the survival of colostrum-deprived calves; serum sodium and potassium in young calves; milk requirements of the calf for growth.

Physiology

Endocrine control of the mammary gland. Mammary growth and lactation in the goat; adrenalectomy and lactation in the goat; neural control of milk secretion in the rat; the role of oxytocin in prolactin secretion.

Physiology of the udder. The synthesis of fat by the perfused isolated bovine udder; the role of the sucking stimulus in the maintenance of lactation; protein synthesis *in vitro* in surviving mammary gland slices.

Bacteriology

Dairy hygiene. Chemical sterilisation—laboratory tests, the can test, farm trials, immersion cleaning, germicidal rubber trials; a new rejection test for faulty milk; heat resistance of bacterial spores; spore germination at low temperatures; sporicidal efficiency of “ultra-high-temperature” treatment; sterilisation of bottles.

Cheese research. The flavour-producing substances in cheese; lactic acid bacteria in Cheddar cheese; impurities in rennin.

The study and classification of lactobacilli.

The microflora of the bovine rumen, and of the alimentary tract of the pig and the chick, in relation to the effect of antibiotics on growth.

Udder health. Effect of machine milking, prolonged milking, age of animal and other factors on susceptibility to natural and artificial udder infection.

Classification of bacteria. *Leuconostoc* group; a new method of classification using paper chromatography; serological typing of various streptococci.

The department also houses the National Collection of Dairy Organisms and provides authentic cultures of specific organisms for workers in dairy research and technology.

Chemistry

Factors affecting the efficiency of food utilisation in the cow. The effect of changes of ration; composition of ration and fat content of milk; measurement of body composition; nutritional value of structural carbohydrates of herbage; quality of silage.

Factors affecting the composition of milk.

Determination of total solids in milk. Permeation of antimycotics into cheese.

Proteins of milk. The two B-lactoglobulins and their mode of inheritance; the proteins of whey; heat denaturation of milk proteins.

Physics

Absorption, scattering and reflection of light in the ultraviolet, visible and infra-red regions of the spectrum, by milk and dairy products; the infra-red spectrum of flavour-constituents in cheese.

Milk clotting. The processes involved in clotting by rennin.

Crystallisation of fat in ice-cream.

Spreading and adhesive properties of butter.

Bovine cervical secretions. Flow birefringence; effect of hormones and physiological conditions on physical properties; chemical composition and changes.

Engineering

"Ultra-high-temperature" sterilisation of milk. Heat stability of milk for condensing and evaporating.

Bulk milk cooling and storage on farms.

Immersion cleaning of milking apparatus.

Performance testing of dairy machinery and equipment, both of prototypes and of equipment and machines on the market.

Development of a farm heat pump.

Nutrition

Nutritional value of milk. The biological value of milk proteins; the effect of heat treatment; the effect of processing on the vitamin composition of milk.

Stability of carotene and vitamin A in feedingstuffs.

Assay, absorption and "binding" of vitamin B₁₂. Protection against destruction in milk during sterilisation; vitamin B₁₂-like compounds.

Vitamin synthesis in the ruminant, particularly by the rumen micro-organisms.

Vitamin D content of pastures, of hay, and of certain supplements to feedingstuffs.

Antibiotics in relation to nutrition.

The department also houses a small Development Commission unit concerned with the metabolism of vitamin A and vitamin B₁₂ in the chain of sea life.

Isotopes section

Biochemical studies in mammary tissue. The tricarboxylic acid cycle in gland slices; pathways of glucose metabolism; biosynthesis of carbohydrates; oxidation of doubly-labelled acetate by mammary tissue of different species.

Biosynthesis of milk fat in perfused bovine udder.

Fractionation of lipid materials for analysis.

The metabolism of radioactive sex hormones.

Isotope assay for other departments.

Statistics section

Co-operative research with departments, both in research planning and evaluation.

General biometry; studies of specialised problems.

Experimental dairy

Collaboration with various departments in milk processing investigations; on milk containers; preparation of special butters; preparation of butter-milk for xanthine oxidase work.

Cheesemaking; cheese without starter; aseptic cheese; different capping and bandaging materials; use of penicillinase in milk from penicillin treated cows; control of cheese mites.

Use of detergents to prevent deposition of milk solids.

Liaison unit

Ripening of cheese in film or foil; wrapping material for cut cheese; and deep freezing of cream.

OUTCOME OF RESEARCH

Dairy farming

(a) *Milk yield and quality.* The importance of the energy (starch equivalent) content of the diet for the maintenance of the protein content of the milk; the influence of the physical character of the diet on fat percentage in the milk; the relation between rumen efficiency and milk fat secretion; an improved method for determining the freezing point of milk; improvements in methods of milk analysis; the effect of hormones (oestrogens, thyroid-active substances) on mammary growth, milk production and milk quality; the discovery, isolation and identification of oestrogens in pasture plants; the value of kale as a winter feed; improvement of milk yields per acre; improved tests for the keeping quality of milk; the factors affecting the vitamin content of milk.

(b) *Milking technique and cowhouse practice.* The control of milking rate by modifications in the milking machine; the anatomical reason for varied milking rates; other factors affecting milking rates and their control; factors concerned in the control of the incidence of mastitis; improvements in detergency and in the sterilisation of farm utensils, including the new method of immersion cleaning; the practical significance of the hormone-controlled "let-down" of milk.

(c) *Other findings.* Practical methods of preventing hypomagnesaemia in spring-grazing cattle; pregnancy diagnosis in the cow by physical means; the value of antibiotics in the feeding of pre-ruminant calves; new methods for performance-testing of dairy machinery, of equipment, of sterilising and cleansing agents; the value of synthetic oestrogens and of copper in increasing growth rate of pigs; the improvement of silage-making techniques.

Milk utilisation

(a) *Liquid milk.* Definition of conditions necessary for efficient H.T.S.T. pasteurisation; devising of new tests to control efficiency of pasteurisation and sterilisation; deep-freezing (after ultrasonic treatment) of milk and cream; the negligible effect of pasteurisation on the nutritional value of milk and the rather larger effect of sterilisation; the deleterious effect of light on the vitamin C and riboflavin of milk; the discovery, isolation, crystallisation and chemical composition of the antibiotic nisin, which destroys the usual mastitis-producing organisms and also *M. tuberculosis*, and the demonstration of its value in dairy industrial processes.

(b) *Milk products.* Improvement in the keeping quality of spray-dried whole milk; practical methods for the prevention of the deleterious effects of bacteriophages on starter used in cheesemaking; physical tests for cheese quality; isolation and crystallisation of the enzyme rennin; ripening of cheese in film and foil; control of butter quality by conductivity determinations.

Fuller details of the research carried out at the Institute are given in the published Annual Reports.

HANNAH DAIRY RESEARCH INSTITUTE

Kirkhill, Ayr

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BIOCHEMISTRY

Head of Department: E. C. Owen,
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W. Manson, B.Sc., Ph.D.

GRASS AND DAIRY HUSBANDRY

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Head of Department: P. S. Blackburn,
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Head of Department: R. Waite, M.Sc., Ph.D.
J. C. D. White, B.Sc., Ph.D.

Secretary: Miss M. M. Hughes

Librarian: Miss E. T. Davidson

The formation of the Institute was made possible by the generous gift in 1928 of the Estate of Auchincruive and the 135 acre Kirkhill farm by the late John M. Hannah, from whom the Institute takes its name. The original buildings were opened in 1931 and these were greatly extended in 1951. Since then it has become clear that the programme of work calls for further building. The research into the important subject of energy metabolism of cattle requires respiration chambers and ancillary laboratories and equipment. Similarly the work on heat tolerance and the effect of climate on the physiology of cattle needs special facilities in the shape of climatic rooms in which the cattle can be kept under a variety of rigidly controlled climatic conditions. Work on these two projects, the latter with financial help from the Colonial Office, is now well advanced and it is hoped that all the extensions will be brought into use during 1958.

The scientific and experimental staff of the Institute on 31st March 1957 numbered twenty-eight.

The work of the Institute covers the biological problems relating to the production of milk and the technical problems associated with the handling of milk before and after it leaves the farm. The biological problems include the production and management of grass and of other crops grown for feeding-stuffs, the nutrition of cattle from birth to maturity and throughout lactation, milk secretion and milk composition, the effect of climate on cattle and the eradication or control of mastitis. The technical problems include improvement of the bacteriological quality of milk (e.g. by improved methods of sterilizing dairy utensils and of cooling milk on the farm) and problems associated with pasteurised, sterilised and dried milk.

CURRENT WORK

Grass and Dairy Husbandry. The Institute's farm is managed by this department. The main object of the work is to study and develop methods by which a high level of milk production, per acre and per cow, may be obtained with the smallest use of imported feedingstuffs. To this end much work has been done on intensive methods of grass production and also on the efficiency with which pasture and the grass products made from it are used.

Several series of experimental grass plots, some of which have been laid down for some years, have been continued. The object of the work on one of

these series of plots is to determine the long-term effects of heavy nitrogen dressings with and without phosphate and potash. The object of another is to examine the effect of closeness of cutting, stage of growth at defoliation and the times of applying nitrogen on the yield of herbage. Several different strains of grasses with and without clover are used in these tests, and the systems that give the most promising results in the small plot work are later used on a farm scale.

During the past few summers various grazing trials have been made to study how herbage can be used efficiently to increase the output of milk per acre; and during the winters experiments have been conducted to determine to what extent dried grass, hay and silage can replace concentrates in feeding the herd for milk production without loss of efficiency and without harm to the health of the herd.

Biochemistry. A study has been made of the ability of a lactating ruminant to synthesise the amino-acid lysine which is an essential constituent of the diet of non-ruminants. Other work has involved the study of the effect of hormones, including thyrotropin and a growth hormone preparation, on the yield of milk and on its content of certain vitamins, particularly vitamin A, thiamine and riboflavin. In the course of this work the value of chromium sesquioxide in determining the digestibility of carotene in the ruminant has been established. A third type of work in this department is a long-term study of the chemistry of casein.

Nutrition. The main work of this department is the study of energy metabolism in ruminants and the ability of different feedingstuffs to satisfy the energy requirements of growth, maintenance and lactation. It is a complex and difficult subject, but considerable progress has already been made. Much of the past year has been devoted to building some of the intricate equipment essential for this type of investigation. In the near future several respiration chambers suitable for calves or sheep and one suitable for a lactating cow, all built at the Institute, will be in full use.

In the Nutrition Department attention is also being given to the nutrition of the very young calf, and in recent years much work has been done with calves on (a) vitamin E metabolism and myopathic disorders, (b) magnesium metabolism in relation to hypomagnesaemic tetany, and (c) the occurrence of calcinosis.

Physiology. The work of this department has consisted of a long-term study of the physiology of temperature regulation, heat tolerance and acclimatisation in cattle. The basic knowledge obtained will ultimately be related to the important problem of increasing the productivity of cattle in tropical and semi-tropical areas of the world, and possibly also to problems associated with the housing of dairy cattle in temperate climates. In recent years the work has included studies of (a) the mechanism, measurement and duration of acclimatisation in calves exposed to high temperatures and humidities, (b) the effect of coat characteristics on heat tolerance and acclimatisation in calves, (c) climatic and physiological factors affecting moisture vaporization through bovine skin, (d) the physiology of thermally induced polypnoea in calves, (e) the location of arterio-venous anastomoses in the bovine animal, (f) the neuro-histology of cattle skin, (g) the physiology of sweating in cattle, and (h) the development of techniques for the accurate measurement of moisture vaporization and for applying portable "mask" methods of measuring heat production with resistance-free circuits.

Veterinary Pathology. Mastitis, which, in its many forms, is still one of the greatest sources of loss in dairy farming today, is the chief subject of research under this heading. A study of both clinical and sub-clinical forms of mastitis, their treatment and control, is being made in nine herds situated within working

distance of the Institute. For some cows the course of the disease is followed bacteriologically and by cell count through one or two lactations, and later, when the animals are slaughtered, the udders of the cows are obtained and examined histologically to assess the amount of tissue damage. This examination is then related to the severity and type of mastitis observed while the cows were in milk. A study of the anatomy of the udder has recently been made with particular reference to the finer ducts of the mammary gland system. This has been of great help when the lesions that occur in mastitis of different types and different degrees of severity have been examined in detail.

Bacteriology. A study is being made (a) of the growth of bacteria in sterilized milk, and (b) of the inter-relation of the growth of coliform and other bacteria in raw milk. In milk sterilized under vacuum the rate of germination of some species of aerobic spore-forming bacilli has been shown to be delayed compared with the rate of germination in milk given the same heat treatment but held in bottles open to the air. Studies of delayed germination originally made at 37° have been extended to include observation at 22° to obtain information relating to the keeping quality of sterilized milk.

In Scotland in recent years many milks of very low total count have been failing the coliform test, and it has been suggested that lack of competition from other species of bacteria may enable the coliform bacteria to grow more rapidly in the milk or to produce gas more readily in the coliform test. A study is therefore being made of the relationship between the growth of coliform bacteria and the numbers and types of bacteria likely to be associated with coliform bacteria in raw milk and in the presumptive coliform test.

Technical Chemistry. In this department research is being done on fresh milk, on dried milk and also on the chemistry of grass. The work on fresh milk is concerned with the non-fatty solids content of milk and factors that influence it. Long-term experiments have been made to study the influence of heredity on the level of the solids-not-fat, and several short-term feeding trials have been used to obtain information on the changes that occur in solids-not-fat content when the amounts of protein equivalent and starch equivalent fed to lactating cows are altered, and when dried grass, hay or silage are used to replace concentrates in the rations. The accuracy of rapid methods of estimating the solids-not-fat content of milk has been studied, and assistance has been given to the Scottish Milk Records Association in their work to establish a suitable method of testing milk for non-fatty solids content on farms. Other long-term work on fresh milk includes an investigation of the factors that control the coagulation of protein in milk.

Recent work on dried milk has been concerned mainly with improving the "wettability" and the keeping quality of dried whole milk.

A detailed investigation is being made of the nitrogen-free extractives fraction of grass which often constitutes as much as 50 per cent of the dry matter of grass. A scheme for analysing this complex fraction has been devised and has been applied to four perennial grasses and one annual grass at four different stages of growth.

OUTCOME OF RESEARCH

One of the ways in which the Institute's work is disseminated is by holding conferences for advisory officers and others, and by members of the staff reading papers at meetings of scientific societies and at meetings of advisory officers and farmers. These meetings always stimulate interest and discussion, but particular attention might be drawn to three subjects which have led recently to results of immediate practical application.

The first is the work of the farm. In this country which produces only 40 per cent of its own food, any increase in the efficiency with which home-grown foods can be made and used is obviously of great importance. The work at Kirkhill which seeks to attain maximal production per cow and per acre with minimal use of imported concentrates is making a valuable contribution in this direction. In 1939 the amount of grass dry matter actually utilized on the farm was 39 cwt./acre, whereas in recent years it has been in the neighbourhood of 60 cwt./acre, an increase of about 50 per cent. Similarly the long-term work on energy metabolism and the ability of different feedingstuffs to satisfy the energy requirements of ruminants will ultimately give information by which it should be possible to make more efficient use of homegrown feedingstuffs.

Another topic of research which has had immediate application in practice is the work on vitamin E deficiency and muscular dystrophy. As a result of this work it was found that some 25 per cent of the deaths among very young calves in some of the beef-rearing areas in the north of Scotland were due to this disease. Suitable supplementation of the rations with vitamin E at the right times has almost entirely solved this problem.

The work on the non-fatty solids of milk has also proved of immediate value. In the search for more milk per cow at the smallest cost in feedingstuffs there might well be a danger that the composition of milk and therefore its nutritive value would decline. The knowledge gained about the many factors, genetical and environmental, that affect the level of non-fatty solids in milk has proved of considerable value and has been applied on several farms where the composition of the milk was not reaching the accepted minimum standard.

A report on the work of the Institute is published every three years.

POULTRY

A.R.C. POULTRY RESEARCH CENTRE

King's Buildings, West Mains Road, Edinburgh, 9

Director: A. W. Greenwood, C.B.E., D.Sc., Ph.D., F.R.S.E.

GENETICS

Miss J. S. S. Blyth, B.Sc., Ph.D.

R. Osborne, B.Sc., Ph.D.

C. F. Pun, M.Sc., Ph.D.

BIOCHEMISTRY

D. J. Bell, Sc.D., Ph.D., F.R.S.E.

NUTRITION

W. Bolton, D.Sc., A.R.I.C., F.R.S.E.

PHYSIOLOGY

J. C. D. Hutchinson, M.A.

PATHOLOGY

W. G. Siller, B.Sc., Dr.Vet.Med., M.R.C.V.S.

ANIMAL BEHAVIOUR

D. G. M. Wood-Gush, B.Sc., Ph.D.

Secretary: A. B. Totty, B.A.

The Centre was established by the Agricultural Research Council towards the end of 1947 and the Director, at that time a member of the staff of the Institute of Animal Genetics at the University of Edinburgh, was appointed. By the end of 1950 it was housed in its own buildings, adjacent to the Institute of Genetics where poultry investigations had been in progress for many years.

The experimental material at the disposal of the Centre was the Brown Leghorn flock which had been developed for research by the Director and his colleagues during the previous 20 years. Carefully observed over this period

it had formed the basis for a series of studies in breeding (genetics) and reproduction (physiology). The flock, developed from a small foundation group to which no new blood has been introduced over the years, consists of a number of inbred lines, together with crosses between them, and in its performance and behaviour exhibits a range that expresses most of the current problems affecting all aspects of the poultry industry, with the exception of epidemic disease.

The Centre has a number of climatic chambers for controlled environmental experimentation with animals and the results of some of the research carried through in them have created considerable interest, both at home and abroad, focussing attention on the need for a closer control of the hen's environment in commercial practice.

The Centre seeks to accumulate basic and fundamental knowledge of the fowl and to attack the complex problems of the poultry industry on a broad front by the employment of many scientific disciplines.

On 31st March 1957 there were sixteen scientific and experimental staff at the Centre.

CURRENT WORK

Genetics. The major investigations of the section devoted to poultry breeding research are concerned with genotype-environmental interactions in production traits. These interactions, which concern egg production, and hatchability in particular, are among the most complex which the animal geneticist has to deal with. The inbred lines of Brown Leghorns and some of the crosses between them are being compared for performance in intensive floor pens, battery cages, and a constant environment chamber. This work is broadly a pilot test for a comprehensive investigation of the scientific background of hybrid vigour and its effects—problems associated with the recent exploitation of commercial hybrids as an important development in the poultry industry. Although these hybrids cannot at present form part of the national breeding stock, recent work at the Centre has shown that in so far as high rate of egg production is concerned repeated back-crossing may retain some of the initial vigour of the original cross.

Another series of studies consisted of an evaluation of modern methods of selection in poultry breeding of a kind useful to the small breeder. It was also shown that comparisons of sire progenies hatched at different times did not form a reliable basis for assessing the relative breeding worth of males. On the other hand a comparative study of selection methods suggested that progress in flock improvement might be obtainable without trap-nesting if birds to breed from were chosen on the performance of sire families.

The effects of inbreeding on egg production were examined from the flock records of the University of California by a member of the Centre's staff. It was found that one egg was lost for every one per cent increase in the computed coefficient of inbreeding.

Physiology. The main problems under investigation are concerned with the fertility potential of sires, and the possibility of maintaining fowl spermatozoa satisfactorily *in vitro* for artificial insemination. Important differences in the composition of the semen of the cock and the domestic mammals have been revealed by chemical analyses. The observations have suggested new approaches to the work of storing fowl semen *in vitro*. Fowl spermatozoa appear to undergo changes in their tolerance to handling *in vitro*, and it is feasible to believe that this phenomenon might be connected with the well-known seasonal changes in fertility and hatchability. Periodical observations are now being made on the physiological state of spermatozoa parallel with their performance in fertility trials to narrow the search for causes of seasonal changes in the reproductive efficiency of poultry.

Embryology. Prehatching mortality among the Centre's flock is at about the same level as that found in the industry in general. A survey of the inbred lines has been carried out which shows that they tend among themselves to have different patterns of embryonic mortality; some are clearly of genetic origin like the autosomal recessive causing "kidney deficiency" occurring in one line, others are due to more complex genetic situations. A considerable group of non-specific early deaths is also found, and the effects of season on these and on the complex genetic mortality is being followed.

The possibility of altering the sex ratio of the progeny of parents carrying oestrogen implants shows that the effect, if any, comes only through the female. In this case the abnormally high proportion of female offspring found is not due to a selective mortality of males and must be caused by an early action of the hormone on genetic males, though it has not been possible to show that the treatment induces true sex reversal. Since the change of sex ratio is not great (up to about 57 per cent female) this form of hormone treatment is unlikely to be of practical importance, as had been suggested by others.

Nutrition. Studies on the digestibility of carbohydrates by fowls showed that crude fibre and nitrogen-free extractives were of little value as nutritional criteria for poultry diets. The adoption of starch plus sugar as a criterion would provide two marked advantages; a positive estimation would replace the derived nitrogen-free extractives and the digestible carbohydrate could be estimated chemically. A simple method for the estimation of starch plus sugar has been developed.

Studies on the efficiency of food utilisation for egg production, using high and low energy diets showed that, although the low energy birds ate more total food, the intakes of digestible food, the egg production and the cost per year were the same. The low energy diet (mainly oats and wheat offals) compared with the high energy diet showed an annual saving of nearly 2 tons fish meal and over 1 ton of other high protein concentrate per 1,000 birds.

It is of considerable practical interest that in the above experiment, and others, where food consumption was recorded it could be shown that the Brown Leghorn was capable of producing 20 dozen eggs in the pullet year at a total cost of rather less than 30s. per bird for food.

Biochemistry. The erythrocyte-plasma ratio in hens is being continuously studied especially in relation to ovulation and moulting. Evidence is accumulating that it is related to follicular growth. The distributions of small molecules and ions between the erythrocytes and the plasma are frequently very different; whole blood analyses must therefore take note of the erythrocyte volume, which, in laying hens at least, tends to vary considerably from day to day. As haemoglobin and erythrocyte volume are closely related in apparently healthy birds, daily haemoglobin measurements can be used to assess the erythrocyte volume in place of haematocrits which would necessitate repeated withdrawal of quantities of blood. Conditions have been established for the rapid and accurate micro-determination of haemoglobin.

The caecal contents are being analysed from the aspect of absorption from, and excretion into, the organ of tissue metabolites. Appreciable amounts of urea and salts of volatile fatty acids are present. Attempts are also being made to poison selectively the different tissue components of the kidney and to study any resulting changes in diagnostic blood chemistry.

Pathology. In some of the inbred lines of this flock there is a high incidence (over 80 per cent in one particular line) of persistent interventricular foramina. The pathology, the genetic basis and the economic significance of this condition is under investigation.

Central nervous lesions, in some respects similar to those of fowl paralysis, have been induced experimentally in fowls by the injection of homologous nervous tissue with or without adjuvants.

A pathological study of the various types of spontaneous nephritis in the fowl is in progress. These investigations are augmented by the study of nephritis induced experimentally by foreign protein injections, and by allergic means with nephrotoxic turkey serum.

A number of birds confined indefinitely from birth under an equable but completely artificial environment in a climatic chamber remained healthy for $3\frac{1}{2}$ years. In the succeeding 2 years losses due to cancer (adenocarcinoma) approximated 90 per cent. A control group of related birds maintained over this period under the normal conditions of husbandry exhibited a low total mortality (11 per cent) and no adenocarcinoma. The nature of the activating agent is under investigation.

Animal Behaviour. Several facets of the mating behaviour of the domestic fowl have been studied. Selective mating by the hen was found to be operative and to be dependent on the courtship behaviour and conformation of the cock. Since selective mating may be responsible for some early infertility, particularly when breeds are crossed, it is intended to perform further investigations using different breeds, and to examine the possibilities of different rearing systems in order to obviate infertility due to this cause.

The sex drive of cockerels is such that males differ significantly in the rates at which they will mate, and these differences are largely genetically determined. Furthermore, males which mate at medium or low frequencies behave aggressively towards the hen at first and require a period of adaptation with the hen before they will mate. Experiments have been designed to test the effect of different rearing systems on the mating behaviour of the male, and to study the physiological means whereby the genetic differences are expressed. The diurnal rhythm in the mating behaviour of the male is also being investigated and experiments have been performed to study the relationship between the cock's mating activity and its position in the social hierarchy.

Time and motion film studies are being used to examine the daily and seasonal behaviour of fowls under semi-intensive conditions.

HOUGHTON POULTRY RESEARCH STATION

Houghton, Huntingdon

Director: R. F. Gordon, D.Sc., M.R.C.V.S.

Senior Scientific Staff:

L. G. Chubb, M.Sc.

E. G. Harry, B.Pharm., Ph.C.

C. Horton-Smith, Ph.D., D.I.C.

Secretary: W. J. Hall

The Poultry Research Station was established by the Animal Health Trust in 1948 and was re-organised as a grant-aided institute in 1956, jointly financed by the Animal Health Trust and the Agricultural Research Council.

The Station consists of a mansion house, a temporary prefabricated laboratory, control flock and experimental unit, situated on a 70-acre estate. In the spring of 1957 approval was given for the erection of new laboratories, the extension of the production and experimental units and alterations to Houghton

Grange. This work is in progress. The two storey laboratory block will adjoin Houghton Grange which will then house the library, museum, offices, senior and junior common rooms, canteen and conference room. An isolation unit and a water tower are in the course of erection.

The expansion of the Station has been designed to meet the pressing needs of the rapidly expanding poultry industry and the problems arising from the trend towards intensive production. The increase in the density of the poultry population, together with the swing towards intensive units of a larger size, has been accompanied by a concomitant rise in mortality from the leucosis complex, and an increase in the hazards from highly infectious diseases, particularly those of the respiratory system. It has been estimated that mortality causes an annual financial loss of between twenty and thirty million pounds. It is impossible to estimate the further loss from interference with egg production, reproduction, food conversion and carcass quality which results from less severe or even sub-clinical diseases such as protozoan and other parasitic infestations.

The research programme has, therefore, been directed in the main towards the control of diseases of immediate importance to the industry, such as coccidiosis, blackhead and other parasitic diseases, and bacterial infections particularly salmonellosis and fowl typhoid; studies in incubator and brooder hens hygiene, and studies of certain aspects of the leucosis complex. Investigations have, however, also been made in the nutritional and husbandry fields where they have bordered on disease problems, such as the influence of nutrition on the course of certain bacterial infections, the ecology of deep litter, and the possibility of long term effects resulting from the continuous use of antibiotics and other chemotherapeutic substances in poultry rations.

On the 31st March 1957 there were eleven scientific and experimental staff at the Station.

CURRENT WORK

Parasitology. Work is in progress on the isolation of pure lines of coccidial species from the fowl and turkey, the potentiation of anticoccidial compounds, and the selective action of various anticoccidial compounds on intestinal coccidiosis. A study is also being made of the nature of the immune response to coccidiosis in the fowl by surgical techniques and of the problem of speciation and interrelationship of species.

Comparative studies are being made of the life histories of *Ascaridia galli* and *Ascaridia dissimilis* (a species recently recovered for the first time from British turkeys). Since failure has attended efforts to infect fowls with *A. dissimilis*, the extent of its host restrictions is being considered.

A statistical analysis of methods of counting nematode ova and protozoan cysts is being carried out.

Work has been carried out on the chemotherapy of histomoniasis of turkeys. This includes studies on effects of antibiotics on *Histomonas* *in vivo* and *in vitro* and a search for a practical disinfectant against *Heterakis* ova in the field. Observations are being made on the course of histomoniasis in turkeys fed on different diets while a study of the *Histomonas*/*Heterakis* relationship continues.

Recently a strain of *Hexamita* has been isolated from turkeys and attempts to culture these organisms in the allantoic fluid of embryonated hens' eggs have met with some success. Preliminary chemotherapeutical tests with furazolidone have met with good results.

Bacteriology. A determination is being made of the relative pathogenicity to chick embryos of individual species of bacteria of intestinal origin. Histological examination, for the presence of macrophages, of the yolk of embryos and

chicks suspected of having died from bacterial infections of the yolk is being carried out. An investigation is being made of the extent to which ova, and eggs during formation, are contaminated by bacteria present in the blood and oviduct of the hen, together with a determination of factors influencing the growth of bacteria in yolk and albumen.

Investigations are being made of the extent to which bacteria multiply in the incubator at hatching time. Analyses are being made of air and surface contamination in the environment of hatcheries, brooders, battery houses and deep litter houses and the control by aerosols of infection in such environments is being investigated.

A detailed investigation is nearing completion on the efficacy of two live attenuated vaccines in the control of Fowl Typhoid with special reference to breed differences, production of agglutinins and transmission of vaccinal strains either in faeces or via the egg. A study of the establishment of coliforms resistant to antibiotics in chicks fed on varying levels of antibiotics is in progress; the control of egg borne infections in hatching eggs and of rots in "table" eggs by the use of germicidal dips is being investigated.

Pathology and Biochemistry. A study is being made of the pathology and chemotherapy of leucotic disease of the fowl, with reference to the effect of certain antimetabolites on the haematology of the chick and on the growth and progress of transplantable lymphoid tumours.

Since these experimental tumours showed certain histological features distinct from those of field leucosis, a detailed examination is being carried out on the histology of cases of leucosis and fowl paralysis in the poultry flock of the Station. Much of this work is to be undertaken by biopsy and laparotomy of ailing birds. These studies will be correlated with the clinical picture, the autopsy findings and any changes in the chemistry of the blood which may be observed.

In addition studies are going on of the relationship of nutrition to certain bacterial and protozoan diseases of the fowl; and in collaboration with the poultry department at Reading University, of the effect of fish meal on hatchability.

Avian Reproduction. Studies are in progress on the dilution and storage of fowl and turkey semen and its effect on fertility and hatchability. An investigation into the possibility of predicting the fertilising capacity of male birds by the examination of semen by various laboratory tests is also being carried out.

Work on the effect of drug additives, e.g. furazolidone and aminonitrothiazoles, on the reproduction of the fowl is nearing completion.

A long term study is in progress of certain factors—e.g. body weight at varying ages, breast width, shank length, date of first egg, broodiness, fertility, hatchability, embryonic mortality and semen production and density—in a closed flock of super Broad Breasted Bronze turkeys and the possible correlation of these factors with the problems of this breed.

Clinical research. The Station's interest in the practical problems of the poultry industry has been maintained through the diagnostic service which provides material of interest to other departments. The Station undertakes all the diagnostic work for the two major commercial laying trials (the National Laying Test and Poultry Production and Progeny Trials) and this work is of considerable value in estimating the relative incidence of the various diseases in a cross section of the national poultry flock. Diagnostic work is also undertaken for other research institutes. Arising from this service three clinical investigations are in progress.

A study is being made of the "haemorrhagic syndrome", a condition which is becoming of increasing importance in broiler plants. The condition has been

reproduced experimentally and its aetiology and possible association with the use of certain coccidiostats and with intercurrent diseases of mycotic origin is being investigated.

Round heart disease is also increasing with the extension of intensive methods of management, particularly the built up litter system with which, clinically at least, it appears to be associated. Attempts are being made to reproduce the disease and to study its aetiology. A clinical study has been made of a number of outbreaks and the data have been recorded.

An examination is being made of the sensitivity to a range of antibiotics of bacteria isolated from outbreaks of such diseases as erysipelas, pseudotuberculosis and pasteurellosis.

OUTCOME OF RESEARCH

The work of the Station which has probably evoked the most interest in the poultry industry and which has been of the greatest value to poultry farmers has been the establishment of chemotherapeutics for the control of protozoal diseases, coccidiosis and histomoniasis, and of *Salmonella* infections, pullorum disease, fowl typhoid and salmonellosis. A large number of such drugs have been screened and the efficiency of certain sulphonamides, furans and the amino-nitrothiazoles has been established. All are now successfully used in this country.

An extensive field trial carried out by the Station on the use of artificial insemination at the Poultry Production and Progeny Trials in Lancashire in 1951 created considerable interest in this technique within the poultry industry. As a result of subsequent detailed work the technique has found a place in the development of Broad Breasted breeds of turkeys and has provided a tool of value for certain types of avian research.

The work of the Station on methods of incubator hygiene, formaldehyde fumigation and aerosols and the use of germicidal dips in the sterilisation of the shell of hatching eggs has proved of considerable value to the hatching industry in the control of egg borne diseases such as salmonellosis of yolk sac infection. The use of germicidal dips in the sterilisation of egg shells has been extended to cover the control of *Pseudomonas* rots in table eggs. Recently two attenuated vaccines have been elaborated for the control of fowl typhoid. Both have given excellent results under laboratory conditions and an extensive field trial is now in progress in collaboration with the Animal Health Division of the Ministry of Agriculture, Fisheries and Food.

A report of the Station's activities is prepared annually for inclusion in the published report of the Animal Health Trust.

AGRICULTURAL ENGINEERING

NATIONAL INSTITUTE OF AGRICULTURAL ENGINEERING

Wrest Park, Silsoe, Bedfordshire

Director: W. H. Cashmore, C.B.E., B.A., N.D.A.

AGRICULTURAL MACHINERY TESTING

Head of Department: D. I. McLaren,
B.Sc. (Agric.), N.D.A.

P. Hebblethwaite, B.Sc. (Agric.), M.S., N.D.A.
R. D. Richardson, B.Sc. (Eng.)

FIELD INVESTIGATION

Head of Department: F. S. Mitchell,
B.Sc. (Agric.)

R. E. Arnold, B.A. (Agric.)
G. Shepperson, B.Sc. (Agric.)

GRAIN DRYING

Head of Department: J. Woodforde,
M.I.E.E., A.M.I.Mech.E.

P. E. Berry, M.Sc., A.M.I.Mech.E., A.F.R.Ae.S.
M. G. R. Warner, M.A., A.M.I.E.E.

HORTICULTURAL ENGINEERING

Head of Department: E. R. Hoare,
B.Sc. (Eng.), A.M.I.E.E.

A. G. M. Bean, B.Sc. (Eng.), A.M.I.Mech.E.
J. B. Byass, M.A.

R. J. Courshee, B.Sc. (Eng.)

L. G. Morris, B.Sc. (Eng.), A.F.R.Ae.S.

E. S. Trickett, B.Sc. (Eng.)

F. H. Vanstone, B.Sc., Ph.D., A.Inst.P.

J. S. Wolfe, B.A., B.Sc. (Eng.)

INSTRUMENTATION

Head of Department: S. W. R. Cox,
B.Sc., A.Inst.P.

MECHANICAL ENGINEERING

Head of Department: H. J. Hamblin, B.A.

P. H. Bailey, B.Sc. (Eng.), A.K.C.

T. C. D. Manby, M.Sc. (Eng.)

H. J. Nation, B.Sc. (Eng.), A.M.I.Mech.E.

P. A. Taylor, B.Sc. (Eng.)

SOIL MECHANICS

Head of Department: J. C. Hawkins,
B.Sc. (Agric.), N.D.A.

SPECIAL SURVEY

J. K. W. Slater, M.A., M.Sc.

Secretary: J. W. Andrews, F.C.I.S.

Librarian: Miss J. A. Midgley

Scottish Station

Howden, Mid-Calder

Director: W. J. West, B.A., Dip.Agric.

G. Gilfillan, B.Sc. (Eng.), M.Sc., A.R.T.C., A.M.I.Mech.E.

I. M. Robertson, B.Sc., Ph.D.

Secretary: D. Warne

The Institute was set up by the Ministry of Agriculture in 1923 at the University of Oxford under the title of the Institute for Research in Agricultural Engineering. In 1942 it was transferred temporarily to larger premises at Askham Bryan, near York, and in 1947 became one of the State-aided institutes with its own Governing Body and moved to permanent quarters at Wrest Park in Bedfordshire. The move was completed in 1949 by which time the necessary workshops, laboratories and instrumentation had been provided. A Scottish Station was also established in Midlothian.

The function of the Institute is research into and development of agricultural and horticultural machinery. The war years saw a great expansion of work but in the prevailing conditions the programme was predominantly the testing of machinery and the carrying out of *ad hoc* investigations with the object of obtaining the greatest farming effort with existing equipment. Since the war the emphasis has shifted to fundamental research and the development of new

machinery, though the testing service developed during the war has been continued.

The staff of the Institute on 31st March, 1957 included ninety-four scientific and experimental staff. At the Scottish Station the scientific and experimental staff numbered thirteen.

CURRENT WORK

The main activities of the Institute (apart from the testing scheme) are divided into farm surveys, field investigations and research and development.

Farm Surveys. These are being increasingly used to provide the necessary background for research or development. The general pattern of a survey, the selection of a sample and the analysis of the data must conform to a strict technique if the results are to be reliable.

Typical surveys which have been completed include the mechanisation of Welsh Hill Farms, the use of fertilizer distributors and the harvesting of potatoes. The results have proved valuable for discussions on the possibilities of extending mechanisation in the Welsh Hills, for reducing the deterioration of fertiliser distributors, and for the development of a complete potato harvester.

The objective of *Field Investigations* is to relate the use and design of agricultural machinery to the efficient employment of labour and to the practice of good husbandry. The results may indicate better methods of using existing machines or the need for new designs.

The main field investigations have covered haymaking, grain harvesting and the mechanisation of spring cultivations for sugar beet. The haymaking experiments began with an investigation into the relationship between the drying rate in the field and climatic conditions, followed by an examination of the value of various machines for making hay in the field, and methods of collection. The techniques observed included the use of tripods, tetrapods, etc., pick-up baling and barn drying. The objective is to find methods of producing the highest quality material consistent with an economic use of labour.

Grain harvesting experiments established the relationship between the size of combine harvester, the capacity of the drying installation and the grain acreage under various conditions. During the current period attention has been given to the setting of the concave and the drum speed in relation to damage to the grain. It is expected that the practical outcome of the work will be proposals for modifying the design of the combine to allow more latitude in setting.

Investigations into the mechanisation of spring work on sugar beet have included mechanical levelling of the seed bed and the technique and the design of the machines used for this operation and that of down-the-row thinning for reducing the hand labour for 'singling'. Similar experiments have been conducted into the harvesting of potatoes and sugar beet.

Research and development are very closely related. The main objects of research are to provide data for evolving new techniques or designing new machines. At times it may be advisable to develop an experimental machine to prove the results of the research, but in many cases the experimental data is published and made available to designers generally.

Since 1947 overseas mechanisation has played an increasing part in the programme. The export of British machinery has called for special tests to cover, as far as possible, overseas conditions. Co-operation with the Colonial Office has resulted in the establishment of a testing unit in East Africa and special equipment has been designed and built for mechanising Colonial territories. There has been an exchange of information with Commonwealth countries, and European countries have shown interest in international testing standards.

The Soil Department has continued with the measurement of various soil properties such as shear strength, soil to metal friction, workability and soil aeration. Wherever possible the measurements are being studied in relation to the performance of soil working implements. The Grain Department has studied the design and performance of radial drying silos, counter flow grain driers, heat exchangers and oscillating conveyors, with the object of improving the design of grain handling equipment in the future. Other research has included the measurement of grain moisture content and the behaviour of various cereals, including overseas crops, under various drying conditions.

Tractor research has included wheel design and hydraulic transmission. Considerable progress has been made with the latter project and it seems likely to have an important bearing on design of tractors and their equipment in the future. Development work includes projects which have been the logical sequence of research and straight development to fill a pressing need. Machines ready for production include a tractor-mounted continuous action ditch cleaner which will cut and maintain ditches up to 4 ft. deep, and a complete potato harvester with the emphasis on simplicity of design and minimum damage to the potatoes.

Development for Colonial mechanisation includes a complete harvester for groundnuts, threshing machinery for rice and a tractor-mounted tie ridge cultivator for semi-arid soils.

For horticulture, the work has included the development of light and solar energy meters, research into the heating and ventilating of glasshouses with the object of improving efficiency, a study of environmental conditions and their relationship to plant growth and the assessment of water uptake. Development work has included vegetable washing machines, low volume sprayers and automatic watering devices for glasshouses.

Testing Service. The aims of this scheme which covers all classes of tractor and implement with the exception of dairy equipment, are to assist manufacturers in developing new and improved machines and, in the case of production machines, to provide reports on performance for the agricultural public. Tests are made primarily at the request of a manufacturer on payment of a fee and the reports are confidential unless publication is agreed by the entrant.

A comprehensive test for tractors has been drawn up and since 1951 there has been a British Standards Test. For production models the Institute has a Farm Trials Scheme in which a number of tractors are placed on farms selected to cover a range of types of farming. Their performance is recorded over a complete year's work. More recently the scope of tractor testing has been widened further to meet the requirements of tractors working under tropical conditions; a hot room and a dust chamber have been constructed at Wrest Park and high altitude tests are carried out by a testing unit which is operating in East Africa under the technical guidance of the Institute.

Farm implements are tested, under normal working conditions in the field, on land available at Wrest Park and also on a number of farms selected to give as wide a range of conditions as possible. Series tests for each class of machine are being encouraged to make it possible to compare the performance of each type of machine in a particular class. For each full report published by the Institute there is now an abridged version which gives all the essential practical information for the benefit of the farming community.

OUTCOME OF RESEARCH

The following paragraphs give some illustration of the part played by the Institute in the rapid progress made by the agricultural engineering industry in the mechanisation of British agriculture.

In 1951 investigations were started into the down-the-row thinning techniques which had been introduced in the U.S.A. The work included a study of the effect of the technique on (a) economy of singling labour, (b) yield, and (c) efficiency of mechanical harvesting. The information and practical experience gained resulted in a number of machines being on the market by 1957. It is estimated that some 7,600 acres of the 1957 sugar beet crop was mechanically thinned. Other work on the spring mechanisation of sugar beet has included the use of tractor cage wheels and seed bed levelling devices. Information and advice on these topics has been passed to both farmers and interested manufacturers.

The haymaking investigations indicated the desirability of tedding grass immediately after cutting, and this has influenced farm practice. Manufacturers have turned to the type of tedder which is most suitable for this purpose. The results of the investigations into rack and tripod drying have stimulated interest in the making of good quality hay, with the result that a number of mechanical tripping devices are now on the market.

Although research into soil mechanics is long term, some of the results obtained have already been put into practical use. A wavy-edged disc coulter developed for ploughing under difficult conditions has been manufactured in large numbers. Results from research into the soil forces acting on plough bodies have been used by leading plough manufacturers.

The Institute has played an important part in developing an adequate range of drying and storage equipment for combined grain. Apart from technical advice on the design of continuous driers, the platform drier for drying in sacks, and the ventilated silo drier have been introduced, and these have enabled farms with smaller acreages to reduce drying costs and cut capital expenditure. Experimental work on silo construction has resulted in the widespread acceptance of prefabricated metal silos for storing grain on the farm.

Tractor research into wheel performance has been the basis for most modern tractor design. The work on hydraulic transmission has created considerable interest in industry, but it is too early to claim any direct result on agriculture.

Special equipment is designed and developed for other branches of agricultural research. For example, 'Rubbed' sugar beet seed is processed on machines based on the one originally developed by the Institute. Most fertiliser placement equipment is similar in principle to one or other of the experimental machines built for other research stations. Experimental drills for cereal plot work have materially benefited crop husbandry research.

The horticultural industry has been helped in various ways. Work on irrigation equipment, its method of installation, and an assessment of the requirements, have paved the way for considerable expansion in the practice of overhead irrigation. Some of the data has been helpful to water boards and others concerned with water conservation.

Research into the heating and ventilating of glasshouses has resulted in new systems of heating being evolved, giving lower initial cost and reduced running costs; at the same time it is possible to have more accurate control with less labour demand.

Research in co-operation with other stations has enabled the Institute to develop improved spraying machinery for use in orchards, thereby giving economy in the use of chemicals and improvement in the quality of the fruit.

Growers have shown an increasing interest in the washing of vegetables and experimental work on this subject has led to machines being manufactured.

The Institute publishes an annual report containing a summary of the work under each Department.

STATISTICS

A.R.C. UNIT OF STATISTICS

University of Aberdeen, Meston Walk, Old Aberdeen

Director: D. J. Finney, M.A., SC.D., F.R.S., F.R.S.E.

Senior Scientific Officer: M. R. Sampford, M.A., D.Phil.

The Unit was established in October 1954. Under agreement with the University of Aberdeen, the Reader in Statistics is Director of the Unit which is attached to the University's Department of Statistics.

The purpose of the Unit is to make available for agricultural research in Scotland the kind of service provided for England and Wales by the Statistics Department of Rothamsted Experimental Station. This involves giving advice to Agricultural Colleges and Research Institutes on statistical aspects of the planning of research projects and on the analysis and interpretation of results. The Unit also undertakes investigations into statistical theory and methodology that are in any way related to the needs of agricultural research, including problems of theory that arise from questions submitted by staff of the other Institutes.

The staffs of the Unit and the University Department are about equal and, although the two sections naturally differ in function, the policy has been to avoid any rigid separation and to aim at building up a single research team of diverse abilities.

A new building designed for the Department and Unit has just been completed and is now occupied.

CURRENT WORK

For many years, statisticians in the University have assisted the North of Scotland College of Agriculture in the design and analysis of field and animal experiments, and this work has been taken over by the Unit. Help on equally varied problems is now regularly given to the West of Scotland College.

Many of the Scottish Research Institutes, which have not their own statisticians, now use the Unit regularly for help to individual staff members: the most numerous inquiries have come from the Hannah Dairy Research Institute, the Scottish Horticultural Research Institute, the Hill Farming Research Organisation and the Scottish Plant Breeding Station.

The way in which the activity of the Unit develops may be illustrated by the work done for the Grassland Committee of the Scottish Agricultural Improvement Council. In the first instance, the Unit was asked to assist in the statistical analysis of trials of grass strains conducted by the three Colleges in collaboration. Now a member of the Unit's staff is on the Committee, where he takes part not only in the design of new experiments but also in planning research policy and in preparing reports on completed experiments. Similar help is given to the Scottish Milk Solids-Not-Fat Group (a research committee convened from the Hannah Dairy Research Institute and the three Colleges) and the Scottish Subcommittee of the Sugar Beet Research and Education Committee. Help is also given to the Scientific Services Station of the Department of Agriculture for Scotland in the planning and analysis of their work on clonal potato stocks.

At the suggestion of the Scottish Agricultural Improvement Council, the Unit has taken a leading part in initiating sample surveys of farmers' practice in the use of fertilisers and associated matters. With the collaboration of the three Colleges, who were responsible for all the field work, surveys were conducted in six localities in 1956 and reports on these were issued early in 1957. These surveys, very similar to those conducted in England and Wales during the past 15 years, for the first time provide objective information on the types, rates, and methods of application of fertilisers to different crops now used by Scottish farmers.

Surveys of six more localities in 1957 have already begun, and it is hoped that the scheme will continue for several years. A sample survey of calf rearing and mortality in north-east Scotland has been conducted for two years, in collaboration with the North of Scotland College of Agriculture.

One major theoretical study now in progress is concerned with optimal conditions for the selection of new varieties of a crop on the basis of performance in field trials. Several problems in the theory of experimental design have been studied. One member of the staff is continuing work on the estimation of time-mortality relationships, having particular reference to animal experimentation. An inquiry from the Animal Breeding Research Organisation has stimulated theoretical examination of a class of growth curves.

Finally mention must be made of the Unit's contacts with agricultural research workers overseas, particularly within the Commonwealth. These are not only of immediate value but, by broadening experience of research problems and techniques, are likely to be of long term benefit to the Unit's activities in Scotland.

A.R.C. STATISTICS GROUP

School of Agriculture, University of Cambridge

Officer-in-charge: R. C. Campbell, M.A., Ph.D.

When the Unit of Reproductive Physiology and Biochemistry was set up in 1954, the statistical group which had been associated with the former Unit of Animal Reproduction became, for a time, a part of the new organisation. Subsequently the Council decided that Dr. Campbell and his staff should be constituted a separate entity, professionally responsible to Dr. Yates, Head of the Statistics Department at Rothamsted, and the Group was established on these lines on the 1st January, 1956.

The Group is available to give advice and assistance in the design and analysis of animal experiments. The main lines of study are at present concerned with artificial insemination in cattle and poultry and with carcass quality of cattle and pigs; the Group is associated with experiments on animal diseases at Compton and with the Agricultural Research Council's Co-ordinated Pig Experiments.

STATE-AIDED AGRICULTURAL RESEARCH INSTITUTES

England and Wales

Rothamsted Experimental Station	...	Harpenden, Herts.
East Malling Research Station...	...	Maidstone, Kent.
Grassland Research Institute	...	Hurley, Maidenhead, Berks.
Agricultural and Horticultural Research Station.		Long Ashton, Bristol.
National Vegetable Research Station	...	Wellesbourne, Warwick.
Welsh Plant Breeding Station	...	Plas Gogerddan, Aberystwyth.
John Innes Horticultural Institution	...	Bayfordbury, Hertford.
Glasshouse Crops Research Institute...		Rustington, Littlehampton.
Research Institute of Plant Physiology...		Imperial College of Science and Technology, London, S.W.7.
Plant Breeding Institute	...	Trumpington, Cambridge.
National Institute for Research in Dairying.		Shinfield, Reading, Berks.
Foot and Mouth Research Institute	...	Pirbright, Woking, Surrey.
(Animal Virus Diseases).		
Poultry Research Station	...	Houghton Grange, Houghton, Huntingdon.
National Institute of Agricultural Engineering.		Wrest Park, Silsoe, Beds.

Wye College Hop Research Centre ... Ashford, Kent.

Scotland

Macaulay Institute for Soil Research	...	Craigiebuckler, Aberdeen.
Scottish Horticultural Research Institute		Mylnefield, Invergowrie, Dundee.
Scottish Plant Breeding Station	...	Pentlandfield, Roslin, Midlothian.
Rowett Research Institute	...	Bucksburn, Aberdeenshire.
Hannah Dairy Research Institute	...	Kirkhill, Ayr.
Animal Diseases Research Association		Moredun Institute, Gilmerton, Edinburgh.
National Institute of Agricultural Engineering Scottish Station.		Howden, Mid-Calder, Midlothian.
Hill Farming Research Organisation	...	48, Palmerston Place, Edinburgh, 12.

AGRICULTURAL RESEARCH COUNCIL INSTITUTES AND UNITS

Field Station	...	...	...	Compton, Newbury, Berks.
Animal Breeding Research Organisation				H.Q.: 6, South Oswald Road, Edinburgh, 9.
Institute of Animal Physiology	...			Babraham Hall, Babraham, Cambridge.
Poultry Research Centre	...	...		King's Buildings, West Mains Road, Edinburgh, 9.
Unit of Biometrical Genetics	...	...		Department of Genetics, Birmingham University.
Unit of Embryology	...	...	...	Department of Zoology, University College, Bangor.
Unit of Experimental Agronomy	...			Department of Agriculture, Oxford University.
Unit of Insect Physiology	...	...		Department of Zoology, Cambridge University.
Unit of Microbiology	...	...	...	Department of Microbiology, Sheffield University.
Unit of Plant Cell Physiology	...	...		Department of Agriculture, Oxford University.
Unit of Plant Nutrition (Micro-Nutrients).				Long Ashton Research Station, Bristol.
Radiobiological Laboratory	...	...		Grove, Wantage, Berks.
Unit of Reproductive Physiology and Biochemistry.				Molteno Institute of Biology and Parasitology, Cambridge.
Unit of Soil Physics	...	...	...	School of Agriculture, Cambridge University.
Unit of Statistics	...	...	...	Department of Statistics, University of Aberdeen.
Statistics Group	...	...	...	School of Agriculture, University of Cambridge.
Systemic Fungicide Unit	...	...		Wye College, Ashford, Kent.
Virus Research Unit	...	...	...	University Farm, Huntingdon Road, Cambridge and Molteno Institute of Biology and Parasitology, Cambridge.

SCIENTIFIC STAFF NOT ATTACHED TO UNITS

PLANT BIOCHEMISTRY

School of Biochemistry, University of Cambridge

R. Hill, M.A., SC.D., F.R.S.

M. W. Rees

REPRODUCTION

Molteno Institute of Biology and Parasitology, University of Cambridge

Mrs. C. L. Mann, M.D., Ph.D.

VITAMIN ASSAYS

Dunn Nutritional Laboratory, Cambridge

V. H. Booth, B.A., Ph.D.

PHYSIOLOGICAL GENETICS

Poultry Research Centre, Edinburgh

J. H. Sang, B.Sc., Ph.D.

MEAT RESEARCH

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Professor Lord Stamp, M.A., M.D., B.Chir.
J. T. Stamp, D.Sc., M.R.C.V.S., F.R.S.E.

PLANTS AND SOILS

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L. Stenning
Principal M. A. H. Tincker, M.A., D.Sc., F.L.S.
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